April 10, 1997

Mr. Ronald A. Milner, Director
for Program Management and Integration
Office of Civilian Radioactive Waste Management
U.S. Department of Energy, RW 30
1000 Independence Avenue, S.W.
Washington, D.C. 20585

SUBJECT: MEETING SUMMARY FOR THE FEBRUARY 25-26, 1997 IGNEOUS ACTIVITY TECHNICAL EXCHANGE

Dear Mr. Milner:

Enclosed is the meeting summary for the February 25-26, 1997 technical exchange between the staff of the U.S. Nuclear Regulatory Commission and representatives of the U.S. Department of Energy (DOE) which was held at NRC headquarters in Rockville, Maryland. The meeting was also attended by representatives of Nye County, Nevada, the U.S. Nuclear Waste Technical Review Board (NWTRB), the Advisory Committee on Nuclear Waste (ACNW), the U.S. Geological Survey (USGS), and the Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O).

If you have any questions regarding this letter, please contact Sandra L. Wastler of my staff. Ms. Wastler can be reached at (301) 415-6724.

Sincerely,

[Original signed by John Thoma for:]

John H. Austin, Chief
Performance Assessment and HLW
Integration Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Enclosure: As stated (Summary of the Mtg of the 2/25-26/97)
cc: See attached list

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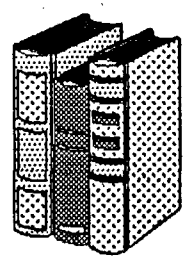
LIST FOR LETTER TO R. MILNER DATED April 10, 1997

cc:
R. Loux, State of Nevada
B. Price, Nevada Legislative Committee
J. Meder, Nevada Legislative Counsel Bureau
W. Barnes, YMPO
C. Einberg, DOE/Washington, DC
M. Murphy, Nye County, NV
M. Baughman, Lincoln County, NV
D. Bechtel, Clark County, NV
D. Weigel, GAO
P. Niedzielski-Eichner, Nye County, NV
B. Mettam, Inyo County, CA
V. Poe, Mineral County, NV
W. Cameron, White Pine County, NV
R. Williams, Lander County, NV
L. Fiorenzi, Eureka County, NV
J. Hoffman, Esmeralda County, NV
C. Schank, Churchill County, NV
L. Bradshaw, Nye County, NV
W. Barnard, NWTRB
R. Holden, NCAI
A. Melendez, NIEC
S. Brocoum, YMPO
R. Arnold, Pahrump, NV
M. Stellavato, Nye County, NV
J. Lyznicki, AMA
A. Gil, DOE

MEETING OF THE FEBURARY 25-26 1997

U.S. NUCLEAR REGULATORY COMMISSION /U.S. DEPT. OF ENERGY



TECHNICAL EXCHANGE ON IGNEOUS ACTIVITY PROGRAM LETTER DATED 4/10/97 102.2

Rec'd w/ltr dtd 9704150198 970410

102.2

Rec'd with letter dated 4/10/97
9704150198 970410

MINUTES OF THE FEBRUARY 25-26, 1997
U.S. NUCLEAR REGULATORY COMMISSION/U.S. DEPARTMENT OF ENERGY
TECHNICAL EXCHANGE ON IGNEOUS ACTIVITY PROGRAM

On February 25-26, 1997, staff from the U.S. Department of Energy (DOE) held a technical exchange with staff from the U.S. Nuclear Regulatory Commission (NRC) at the NRC offices in Rockville, Maryland. The purpose of the exchange was to achieve issue definition on the approach to considering igneous activity in DOE's Total System Performance Assessment - Viability Assessment (TSPA-VA) and identify areas of agreement and disagreement on the relevant geologic data, the probability of volcanism, models for calculating consequences, and performance assessment models of igneous activity for the Yucca Mountain proposed repository.

The selected topics for discussion included geologic setting and relevant data from the NRC and the Center for Nuclear Waste Regulatory Analyses (CNWRA) field studies and ground magmatic surveys in Yucca Mountain Region (YMR), definition of the YMR system, DOE's Probabilistic Volcanic Hazard Analysis (PVHA) results, DOE plans for TSPA-VA, NRC's probability models and their concerns with PVHA source zone definitions, structural setting of YMR relevant to repository, and integrated volcanism structural models. In addition, the NRC presented consequence models for tephra dispersion, subsurface area of dispersion and critical models used in performance assessment (PA), and sensitivity studies performed by the CNWRA. The agenda for this technical meeting is provided in Attachment 1.

Attendees included representatives from the DOE Office of Civilian Radioactive Waste Management (OCRWM), the DOE Yucca Mountain Site Characterization Office (YMSCO), the NRC, CNWRA, Nye County, Nevada, the U. S. Nuclear Waste Technical Review Board (NWTRB), the Advisory Committee on Nuclear Waste (ACNW), the U. S. Geological Survey (USGS), and the Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O). Attachment 2 is a list of the technical exchange attendees.

Opening remarks were made by both the DOE and the NRC. The NRC's view is that there are three potential disruptive scenarios associated with the repository. They are human intrusion, seismic disruption, and igneous activity. The NRC noted that the igneous activity issue is ripe for resolution at the staff level and viewed the technical exchange as an opportunity to determine where the two agencies can reach agreement on approaches for issue resolution and to identify areas of disagreement.

In its opening remarks (Attachment 3), DOE stated that a number of interactions have been held on issues related to igneous activity and potential volcanism hazards, however little resolution has been achieved. DOE expected that the meeting will lead to resolution of NRC's key technical issues (KTIs) related to igneous activity, and that the meeting, if successful, will be used as a model for future interactions related to resolution of KTIs.

Following the introductory remarks, the NRC reiterated the key technical issue which deals with estimating or bounding the consequences and probability of igneous activity affecting the proposed repository in relationship to the overall system performance objective. In order to

resolve this KTI, the NRC outlined five points and sought DOE's agreement on these points (Attachment 4).

DOE then provided a brief presentation of the objectives of the technical exchange, status of the DOE volcanism program, and the DOE analysis of volcanic hazards (Attachment 3). DOE stated that it has decided to close out site characterization data collection for volcanism based on low disruption probability, insensitivity of PVHA results to new data, and an indication of little impact on site performance. DOE plans to evaluate new information and perform additional analysis, as needed, to ensure a sound and defensible position. Also, additional consequence analyses based on available information are planned as part of TSPA-VA. In presenting the results of PVHA, DOE noted that the PVHA resulted in a mean disruption probability of 1.5×10^{-8}/yr with a 90 percent confidence interval of 5.4×10^{-10} to 4.9×10^{-8} /yr and a bounding range of 10^{-10} to 10^{-7}/yr.

For the NRC, the CNWRA presented a brief discussion on its investigation of the YMR geologic setting relevant to igneous activity (Attachment 5). Based on this investigation and the current information, the NRC concluded that silicic volcanism does not need to be considered in evaluating probability and consequences of YMR igneous activity. Another presentation by the CNWRA discussed the regional structural setting of basaltic volcanoes near Yucca Mountain, recent geophysical survey and their significance, and a summary of geological factors to be included in probability models (Attachment 6). The CNWRA concluded that probabilistic models of volcanism should account for features including clustered volcanism in Crater Flat, association of volcanoes and faults, prevalence of north-east trending vent alignments, and a low and persistent recurrence rate. DOE noted that the NRC's findings are consistent with DOE's understanding of NE trending and possible buried volcanoes. The CNWRA suggested that the source zones drive the probability, especially at the low end, therefore, the structure within the zone needs to be incorporated into probability models.

DOE then presented the results of the PVHA for Yucca Mountain (Attachment 3). DOE's presentation described the purpose and an overview of the study, elements of PVHA assessed by the panel of experts, technical assessments made by the experts, and the aggregate results and sensitivity studies. The objective of the PVHA was to assess the probability of disruption by a volcanic event of the proposed repository, and to quantify the uncertainties associated with this assessment. DOE indicated that it intends to use the full distribution of the probabilities in its total system performance assessment. However, the NRC noted that the CNWRA work supported an upper bound of 10^{-7} and suggested it be utilized in analyses to minimize debate over the geologic basis for the lower portion of the probability distribution.

For the NRC, the CNWRA next presented the results of its modeling and analysis of the probability of volcanism in the Yucca Mountain region and disruption of the proposed repository (Attachment 7). The analysis utilized a nonhomogeneous Poisson probability, incorporated geologic structure into probability models using fault maps and potential field geophysical data, and considered dike length relative to probability of intersection. This model indicated that including structural control in volcanic hazard models increases the probability of volcanic disruption of the proposed repository compared to models that do not include structural control.

The NRC wants to have a robust probability number that will carry through licensing.

Both the NRC and the DOE caucused separately to sort out the areas of agreement and disagreement and discuss approaches to a path forward. Following the caucus, both parties discussed areas of agreement and disagreement and approaches for resolution.

The CNWRA, for the NRC, then presented the results of its investigations of igneous activity consequences on repository performance (Attachment 8). The CNWRA described conceptual models for waste incorporation into eruption, subsurface area disruption, transfer of material from basaltic volcanoes, and modeling tephra dispersion with ashplume. The CNWRA noted that the scale of a disruption of Yucca Mountain will most likely be analogous to the 1975 Tolbachik eruption in Russia, and may disrupt 4-10 waste packages if similar events occur in an 83 MTU/acre repository.

On the second day of the technical exchange, the NRC presented the results of annual dose estimates from "preliminary" performance calculations performed in the context of NRC's IPA Phase 2, DOE's TSPA 95, and the NRC staff evaluation of NAS recommendations (Attachment 9). The individual dose estimates were calculated as 0.5 mrem median dose and 4 mrem 90th percentile for the TSPA 95 (5 km, drinking water) and 4.4 mrem median dose and 40 mrem 90 percentile for the NRC/NAS nominal case (30km, all pathways).

A discussion of consequence analyses for a volcanic disruption of the proposed repository by development of a cinder cone, and airborne tephra dispersal was also presented by CNWRA, for the NRC (Attachment 10). Based on reasonably conservative assumptions, the risk for this volcanism scenario, was calculated as 0.5 mrem/year. However, still to be considered in dose calculations are the timing of eruptions, waste incorporation mechanisms, system response to thermal, chemical, and mechanical loads, and dose point locations.

The DOE then presented its plans for incorporation of volcanism into TSPA-VA. The presentation included an overview of previous TSPA 91 and TSPA 93 analyses, a discussion of recent supporting work related to probabilities and consequences, and preliminary plans for TSPA-VA (Attachment 3). DOE concluded that disruptive events will be incorporated into TSPA-VA to the extent that the consequences are expected to be detectable, the probabilities are not negligible, the significance is perceived to be large, and YMP resources permit inclusion. The NRC thinks that based on their research, DOE's intrusion geometry and models will need improvement for representativeness. DOE intends to improve models in TSPA-VA. Also, with regard to waste entrainment models, NRC urged the DOE not to consider only dike geometry and a uniform volume, but to evaluate late stage widening of conduits associated with volcanic eruption.

At the close of the meeting, both parties discussed the DOE/NRC points of agreement and proposed a path to resolve the sub issue of probability of igneous activity. The agreements (Attachment 11) reached by the NRC and the DOE are believed to provide a path forward for resolution of this issue.

Sandra Wastler
Division of Waste Management
Office of Nuclear Material
Safety and Safeguards
U.S. Nuclear Regulatory Commission

Christian E. Einberg
Regulatory Coordination Division
Office of Civilian Radioactive
Waste Management
U.S. Department of Energy

ATTACHMENT 1

AGENDA
DOE/NRC TECHNICAL EXCHANGE - IGNEOUS ACTIVITY PROGRAM
February 25-26, 1997

OBJECTIVE:

To achieve issue definition on the approach to considering igneous activity in TSPA-VA and identify areas of agreement and disagreement at the staff level on the relevant geologic data, the probability of volcanism, models for calculating consequences, and performance assessment models of igneous activity.

GOALS:

At the staff level, exchange information, foster discussion, and determine areas of agreement and disagreement, and paths for pursuing, identifying, and resolving areas of disagreement.

Define the Yucca Mountain Region (YMR) system (spatial, temporal, petrogenetic/isotopic constraints; consider buried volcanic features(i.e., those that may be present but undetected); evaluate evidence of post-caldera silicic volcanism.

Examine technical bases for source-zone definitions; evaluate approaches to incorporating structural models/data into probability models; evaluate geophysical site characteristics relevant to volcanism.

Evaluate the technical basis for performance assessment (PA) abstractions, especially waste incorporation; examine approaches for building confidence in models using geological data.

Examine range of dose estimates from processes; identify and discuss critical uncertainties regarding engineered systems behavior during igneous events; evaluate alternative approaches for understanding geologic processes in disturbed repository setting.

February 25, 1997

8:00	Introduction - Opening Remarks	DOE/NRC/AUG
8:30	Geologic Setting and Relevant Data - CNWRA Field Studies - Definition of the YMR System - Crater Flat 6 Ma Pumice - Ground Magnetic Surveys in YMR	NRC
10:15	Break	ALL

10:30	Probability Models - PVHA Results	DOE
12:00	Lunch	ALL
1:00	Probability Models (Continued) - Concerns With PVHA Source - Zone Definitions - Structural Setting of YMR Relevant to Repository - Integrated Volcanism Structural Models	NRC
2:00	Caucus	ALL
2:30	Wrap up - Areas of Agreement and Disagreement	ALL
3:15	Break	ALL
3:30	Consequence Models NRC Consequence Models - Tephra Dispersion - Subsurface Area of Disruption - Critical Models used in PA Models for Dose	NRC
5:00	Adjourn	ALL

<u>February 26, 1997</u>

8:00	Comments on Previous Day Discussions	ALL
8:30	Sensitivity Studies and Significance - Results of NRC/CNWRA Sensitivities Studies - DOE Plans for TSPA - VA	 NRC DOE
10:30	Caucus	ALL
12:00	Lunch	ALL
1:00	Itemization of agreements/disagreements - Ensure NRC's comments/technical bases and DOE's responses are understood - Make modifications to suit	NRC/DOE
3:00	Closing comments	ALL
3:30	Adjourn	ALL

ATTACHMENT 2

NRC-DOE TECHNICAL EXCHANGE ATTENDANCE LIST
IGNEOUS ACTIVITY
February 25, 1997
NRC - Two White Flint , 11545 Rockville Pike, Rockville, MD

NAME	ORGANIZATION	TELEPHONE
Carl Stepp	M&O/WCFS	512-338-0620
Klen Chang	NRC/DWM	301-415-6612
Stephen Brocoum	DOE	702-295-9611
Phillip Justus	NRC/DWM	301-415-6745
Jean Younker	DOE	702-794-7650
Robert Gamble	M&O/WCFS	703-204-8520
John Austin	NRC/NMSS/DWM	301-415-7252
Bill Reamer	NRC	301-415-1640
David Brooks	NRC	301-415-7282
John O. Thoma	NRC	301-415-7293
Keith I. McConnell	NRC	301-415-7289
Michael Bell	NRC/NMSS/DWM	301-415-7286
Robert L. Johnson	NRC/NMSS/DWM	301-415-7282
April Gil	DOE/YMP	702-794-5578
Ali Haghi	M&O/DUKE	702-295-4873
Wesley C. Patrick	CNWRA	210-522-5150
Bakr Ibrahim	NRC/DWM	301-415-6651
Tim Sullivan	DOE	702-794-5589
John Trapp	NRC	301-415-8063
Bob Youngs	Geomatrix	415-434-9400
Rick Carlson	Carnagie Inst Washington	202-686-4370
Norman Eisenberg	NRC	301-415-7285
Jan Docka	M&O/Intera	703-205-3829
W.G. Nelson	WTRB/Smithsonian	202-357-1947
Frank Perry	LANL	505-667-1033
Stan Echols	Winston & Stawn	202-371-5777
Linda Kovach	NRC/RES	301-415-6266
Sam Colwell	SC&A, Inc.	703-893-6600
Nick Stellavato	Nye County	702-295-5142
Sandra Wastler	NRC	301-415-6724
Chris Einberg	DOE	202-586-8869

NRC-DOE TECHNICAL EXCHANGE ATTENDANCE LIST
IGNEOUS ACTIVITY
February 25, 1997
NRC - Two White Flint , 11545 Rockville Pike, Rockville, MD

PRINTED NAME	ORGANIZATION/COMPANY	PHONE
Leon Reiter	NWTRB	703-236-4490
Lynn Deering	NRC/ACNW	301-415-6887
Martha Pendleton	M&O/WCFS	702-295-5550
Ray Wallace	USGS	202-586-1244
Bret Leslie	NRC/DWM	301-415-6652
Kevin Coppersmith	Geomatrix	415-434-9400
Tim Hawe	DOE	702-794-1441
Larry McKague	CNWRA	210-522-7724
Richard Quittmeyer	M&O/WCFS	702-295-3551
Steve McDuffie	NRC	301-415-1085
Brittain Hill	CNWRA	210-522-6087
Mike Clive	BAH	702-794-5481
Ken Ashe	M&O/Licensing	702-295-5563
Paul W. Pomeroy	ACRS/NRC	914-339-1715
Gene Rosenboom	USGS	301-530-1059
Mysore Nataraja	NRC/DWM	301-415-6695
Bill Hinze	ACRS/NRC	765-383-2530
Chuck Connor	CNWRA	210-522-6649
Nancy J. Chappell	DOE	702-794-1928

NRC-DOE TECHNICAL EXCHANGE ATTENDANCE LIST
IGNEOUS ACTIVITY
February 26, 1997
NRC - Two White Flint, 11545 Rockville Pike, Rockville, MD

NAME	ORGANIZATION	TELEPHONE
Carl Stepp	M&O/WCFS	512-338-0620
Stephen Brocoum	DOE	702-295-9611
Phillip Justus	NRC/DWM	301-415-6745
Robert Gamble	M&O/WCFS	703-204-8520
John Austin	NRC/NMSS/DWM	301-415-7252
David Brooks	NRC	301-415-7282
John O. Thoma	NRC	301-415-7293
Michael Bell	NRC/NMSS/DWM	301-415-7286
Robert L. Johnson	NRC/NMSS/DWM	301-415-7282
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Bakr Ibrahim	NRC/DWM	301-415-6651
Tim Sullivan	DOE	702-794-5589
John Trapp	NRC	301-415-8063
Bob Youngs	Geomatrix	415-434-9400
Norman Eisenberg	NRC	301-415-7285
W.G. Nelson	WTRB/Smithsonian	202-357-1947
Frank Perry	LANL	505-667-1033
Sandra Wastler	NRC	301-415-6724
Raison Barnard	M&O/SNL	505-848-0738
Virginia Colten-Bradley	NRC/DWM	301-415-6616
Alan Brownstein	DOE/HQ	202-586-4973
Alexandra Strohl	Booz-Allen & Hamilton	301-816-7322
Sam Colwell	SC&A, Inc.	703-207-9506
Chris Einberg	DOE	202-586-8869

NRC-DOE TECHNICAL EXCHANGE ATTENDANCE LIST IGNEOUS ACTIVITY February 25, 1998 NRC - Two White Flint , 11545 Rockville Pike, Rockville, MD		
PRINTED NAME	ORGANIZATION/COMPANY	PHONE
Leon Reiter	NWTRB	703-236-4490
Martha Pendleton	M&O/WCFS	702-295-5550
Ray Wallace	USGS	202-586-1244
Kevin Coppersmith	Geomatrix	415-434-9400
Tim Hawa	DOE	702-794-1441
Richard Quittmeyer	M&O/WCFS	702-295-3551
Brittain Hill	CNWRA	210-522-6087
Larry MCKague	CNWRA	210-522-5183
Ken Ashe	M&O/Licensing	702-295-5563
Paul W. Pomeroy	ACRS/NRC	914-339-1715
Gene Rosenboom	USGS	301-530-1059
Mysore Nataraja	NRC/DWM	301-415-6695
Chuck Connor	CNWRA	210-522-6649

ATTACHMENT 3

YUCCA
MOUNTAIN
PROJECT

Studies

DOE-NRC Technical Exchange:

Igneous Activity Program

February 25-26, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

YUCCA
MOUNTAIN
PROJECT

Studies

Igneous Activity Program

Opening Remarks

Presented to:
DOE-NRC Technical Exchange

Presented by:
Dr. Stephan J. Brocoum
Assistant Manager, Licensing
Yucca Mountain Site Characterization Office

February 25-26, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

Path Forward

- Since 1989, there have been seven interactions with the NRC staff on issues related to igneous activity and potential volcanic hazards
- To date there has been considerable discourse with little resolution
- DOE understands NRC management intends to work with DOE to reach resolution on the KTI's prior to submittal of the license application, however, a clear path has not been defined
- It is DOE's position that interactions such as this one must be focused to clearly define a path forward to issue resolution

Path Forward (Continued)

- It is DOE's expectation that this meeting will lead to resolution of NRC's KTI related to igneous activity
- If there is a clear path forward established from this meeting, then it can be used as a model for future interactions related to resolution of KTI's.

YUCCA
MOUNTAIN
PROJECT

Studies

Igneous Activity Program

Introduction

Presented to:
DOE-NRC Technical Exchange

Presented by:
Tim Sullivan
Viability Assessment Team Leader
Yucca Mountain Site Characterization Office

February 25-26, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

OBJECTIVES

- Reach a common understanding of the basis for resolving the Igneous activity Key Technical Issue and its sub-issues
- Identify areas of agreement and define the path forward for areas of disagreement
- Discuss new information and analyses to be presented by the NRC

VOLCANISM PROGRAM STATUS

- DOE will evaluate new information and conduct additional analyses as needed to ensure we maintain a sound defensible position
- Additional consequence analyses based on available information are planned as part of TSPA-VA
- TSPA-VA plans will be described in a later presentation

VOLCANIC HAZARD ANALYSIS

- DOE has completed evaluation of the probability of disruption of the repository and quantified the associated uncertainties based on elicitation of 10 subject matter experts in volcanism
  - final report completed in June 1996
  - intended to provide a sound defensible basis for licensing
- PVHA results
  - mean disruption probability -- 1.5×10^{-8}
  - 90% confidence interval -- 5.4×10^{-10} to 4.9×10^{-8}
  - bounds -- 10^{-10} to 10^{-7}

VOLCANIC HAZARD ANALYSIS

- The NRC Annual Report concludes that the probability of future basaltic volcanic events at the proposed repository site ranges between 10^{-8} and 10^{-7}
- This range differs from DOE's PVHA result, but is included within the bounds of the full probability distribution
- At a previous meeting the PVHA process was discussed, at this meeting the technical basis for the PVHA results will be presented

YUCCA
MOUNTAIN
PROJECT

Studies

Igneous Activity Program

Results of the Probabilistic Volcanic Hazard Analysis for Yucca Mountain, Nevada

Presented to:
DOE-NRC Technical Exchange

Presented by:
Kevin J. Coppersmith and Robert R. Youngs
Geomatrix Consultants
San Francisco, CA

February 25-26, 1997

U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

PROBABILISTIC VOLCANIC HAZARD ANALYSIS (PVHA) FOR YUCCA MOUNTAIN, NEVADA

PRESENTATION OUTLINE

1. **Purpose and Overview of Study**
2. **Elements of PVHA Assessed from Expert Panel**
3. **Technical Assessments Made by Experts**
4. **Aggregate Results and Sensitivities**

PROBABILISTIC VOLCANIC HAZARD ANALYSIS (PVHA) FOR YUCCA MOUNTAIN, NEVADA

OBJECTIVES OF THE STUDY:

1. To assess the probability of disruption by a volcanic event of the proposed repository
2. To quantify the uncertainties associated with this assessment

Disruption: the physical intersection of magma with the potential repository volume
Volcanic event: both eruptive and intrusive features
Probability: annual frequency

ASPECTS OF PVHA STUDY

Quantification of uncertainty was a central focus of the PVHA study. Important aspects of the PVHA uncertainty characterization are the following:

- **Attempting to capture all important elements of uncertainty, including expert-to-expert diversity of interpretation**
- **All of the experts were exposed to all pertinent data, researchers, and methods**
- **Ultimately, the reliance that an expert places on certain data, methods, experience is their prerogative**
- **Experts encouraged to consider full range of methods, data, analogue experience in addressing issues**
- **Focus is on uncertainty not "preferred" estimates; when in doubt, don't choose, weigh the alternatives**
- **Formal process of expert elicitation followed (consistent with BTP, SSHAC, etc.)**

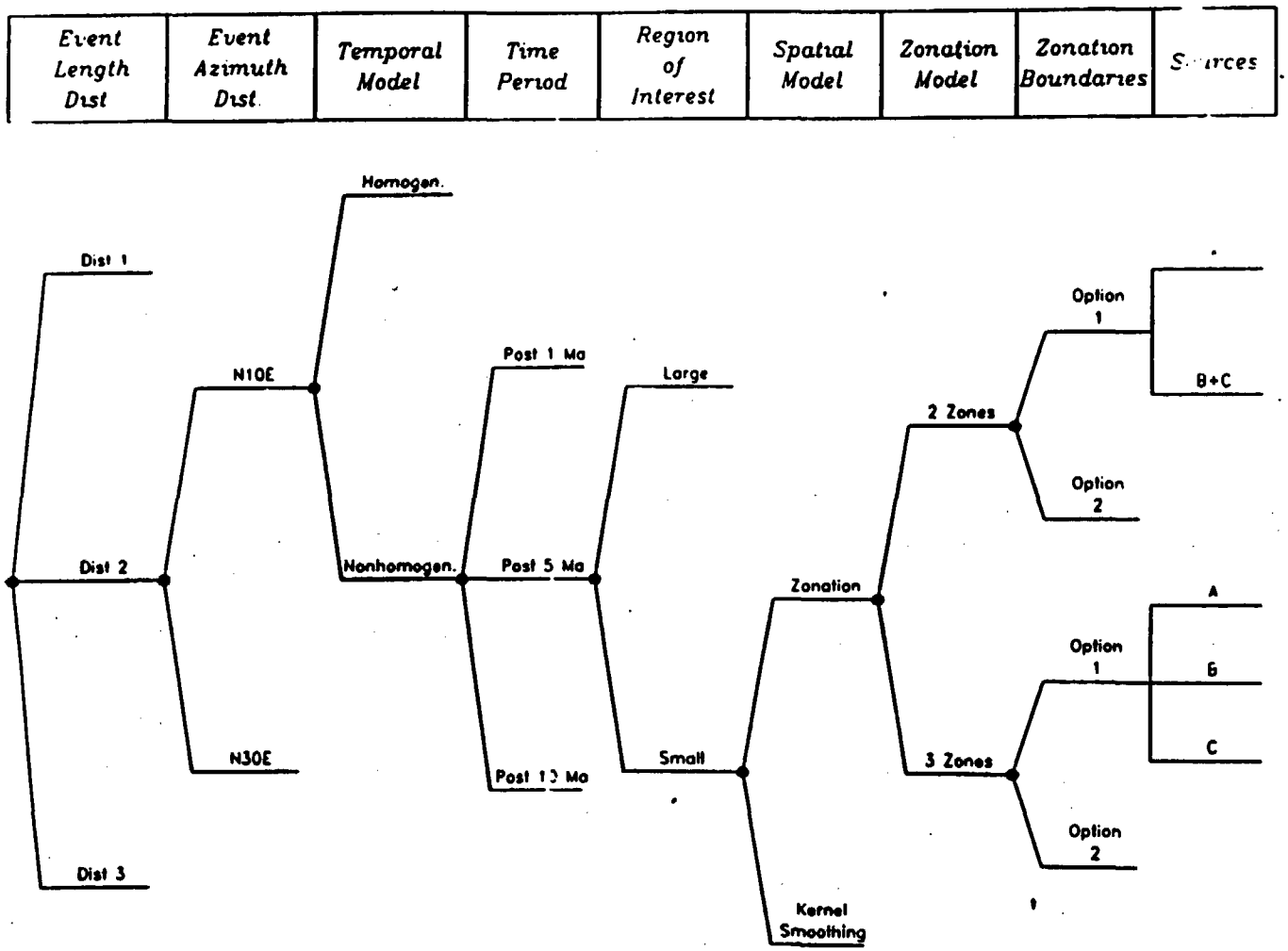


Figure 3-15 General logic tree structure used to construct PVHA computation model.

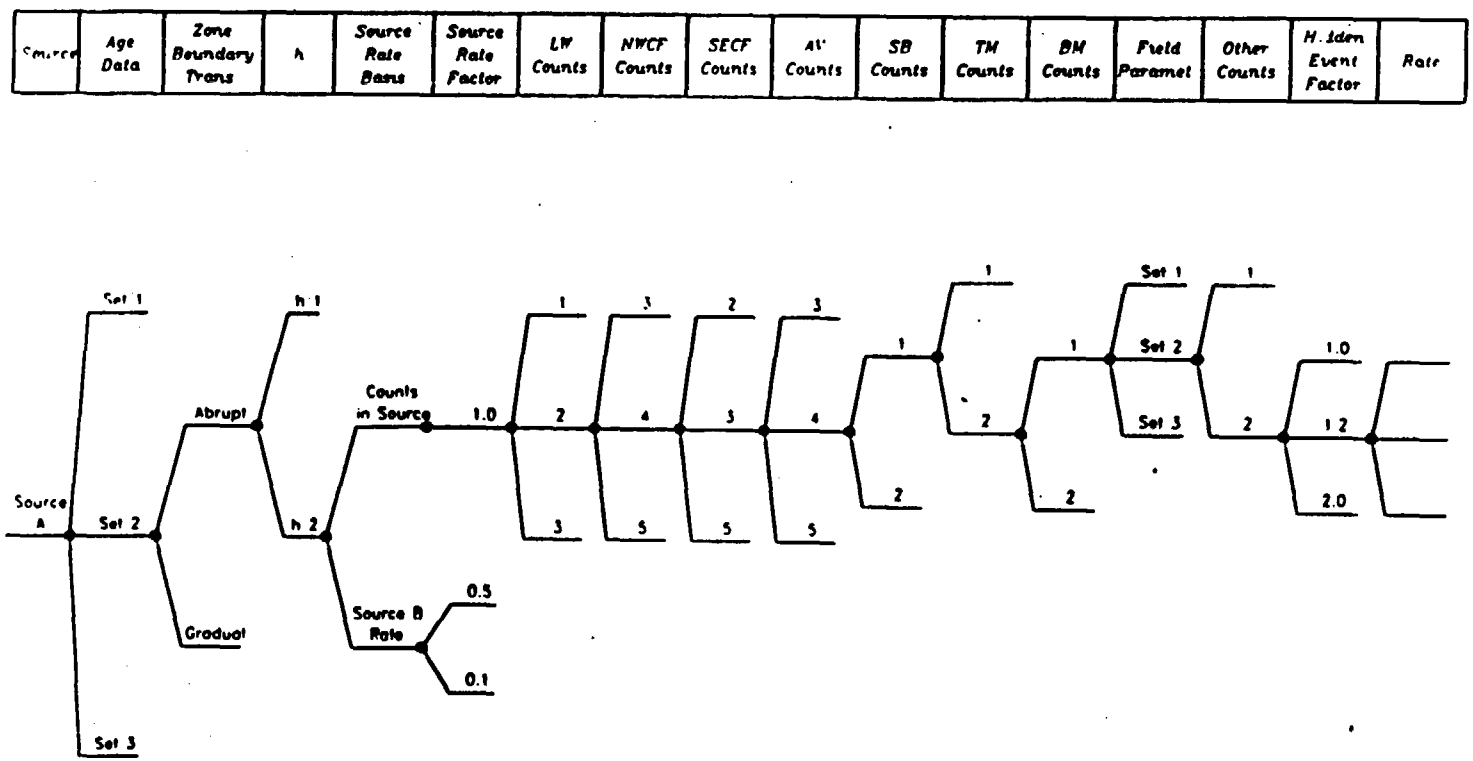


Figure 3-16 Logic tree structure for subtrees addressing the uncertainty in modeling the hazard from specific sources. These subtrees are attached to the overall logic tree shown on Figure 3-15.

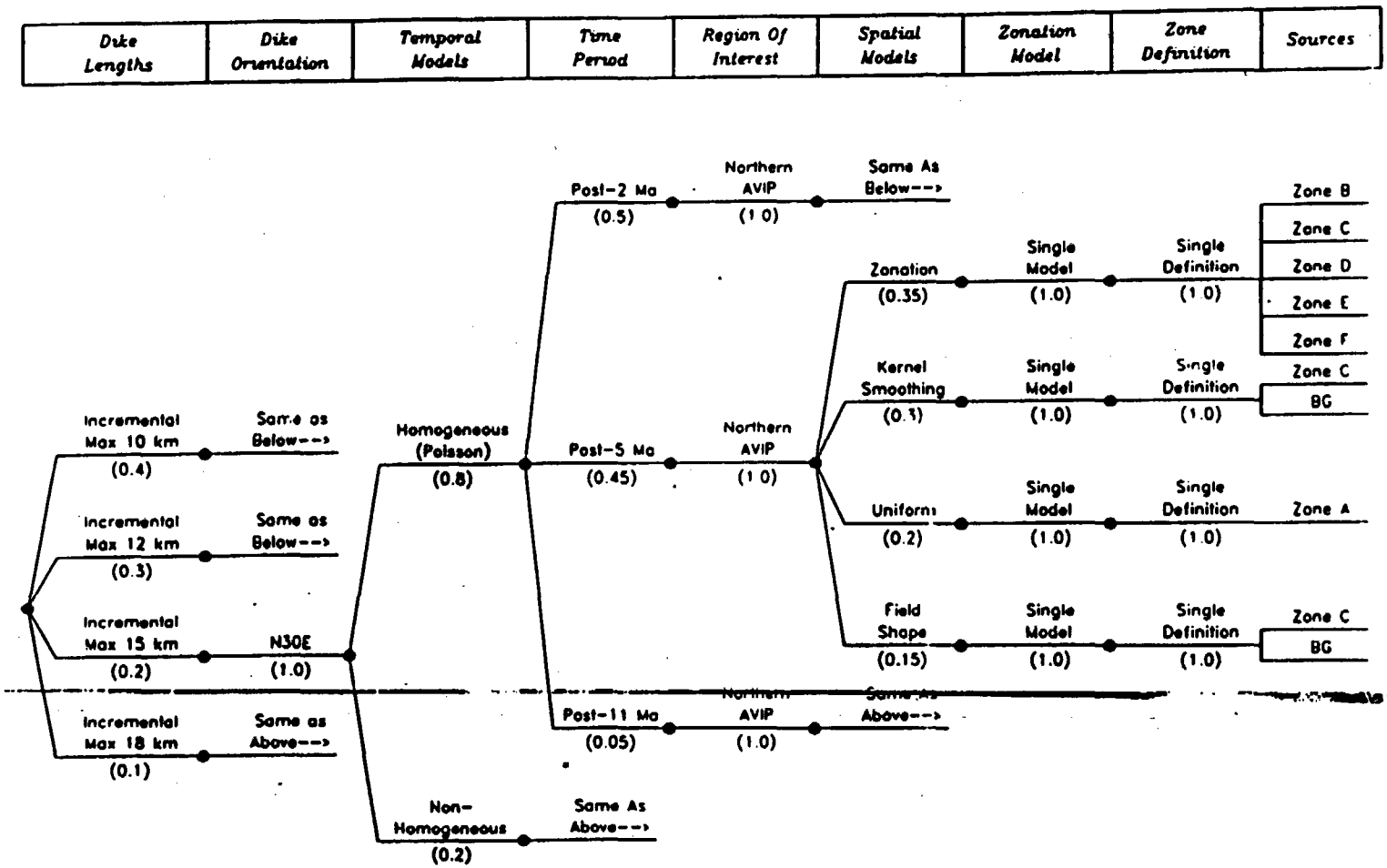


Figure 3-35 Logic tree for the PVHA model developed by Mel Kuntz.

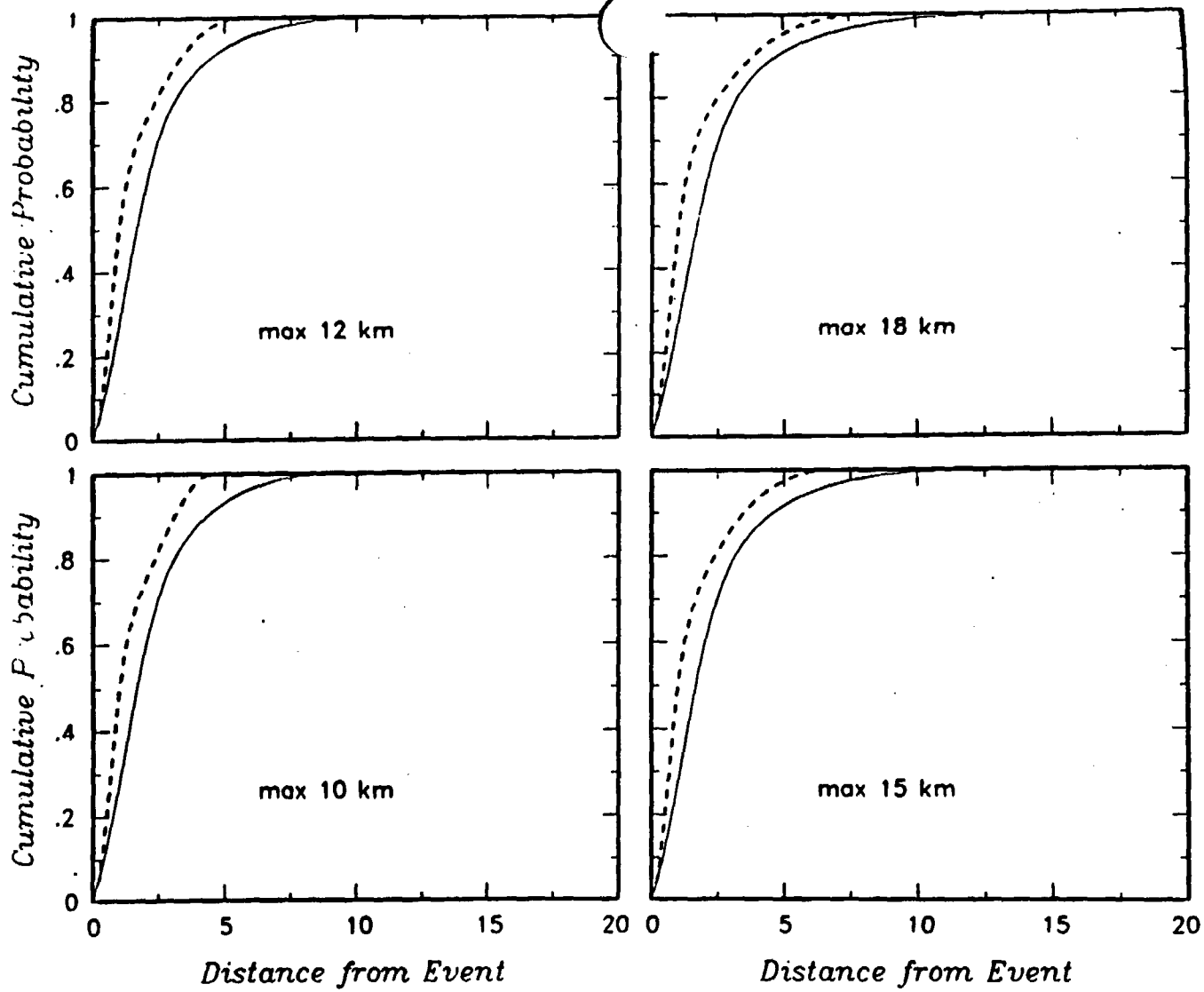


Figure 3-36 Alternative distributions for the length of an event *f(l)* developed from the assessments by Mel Kuntz.

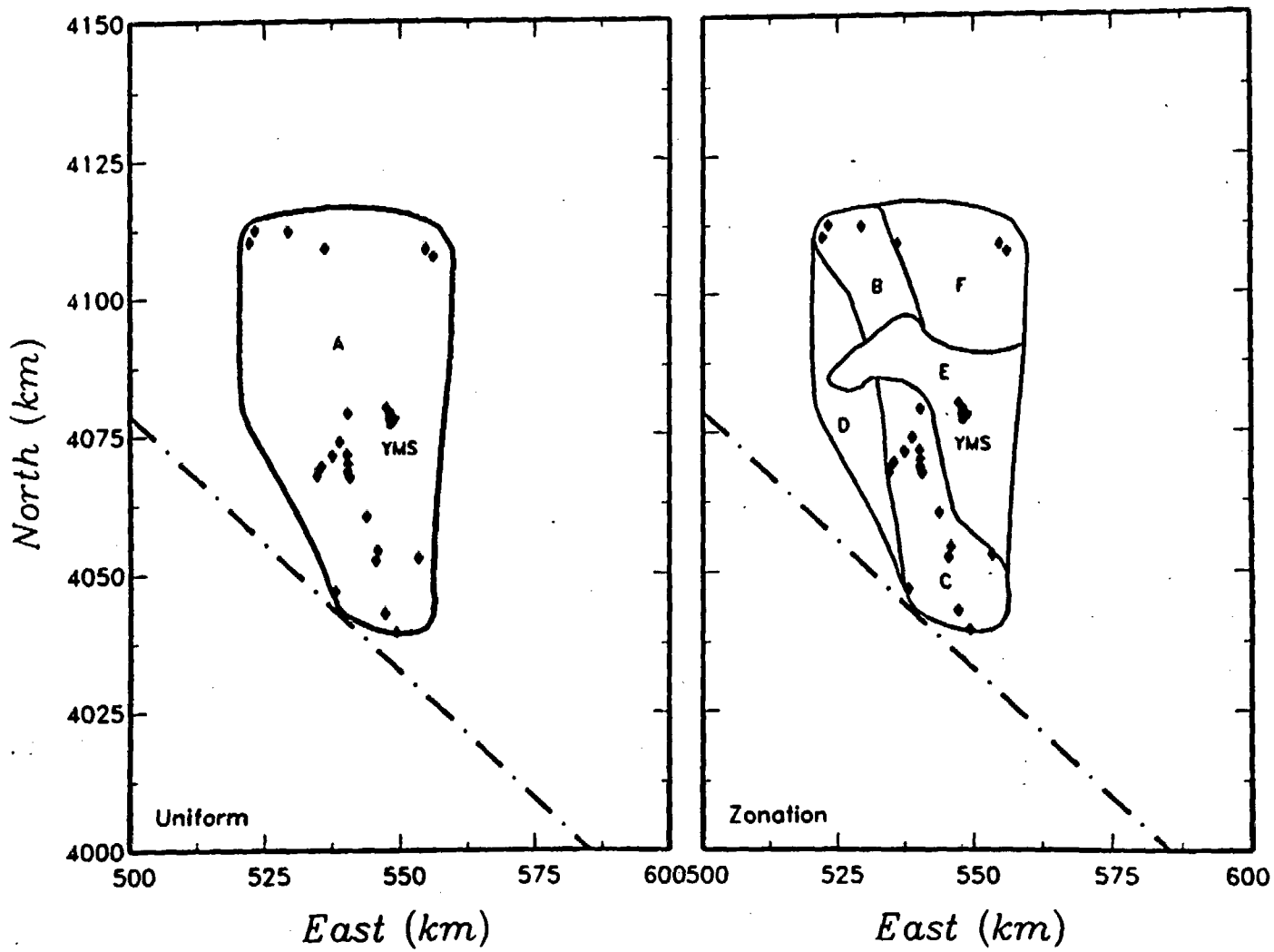


Figure 3-37 Region of interest and volcanic so[illegible] ne model developed by Mel Kuntz. Diamonds represent volcani[illegible] Mountain repository site and th[illegible]

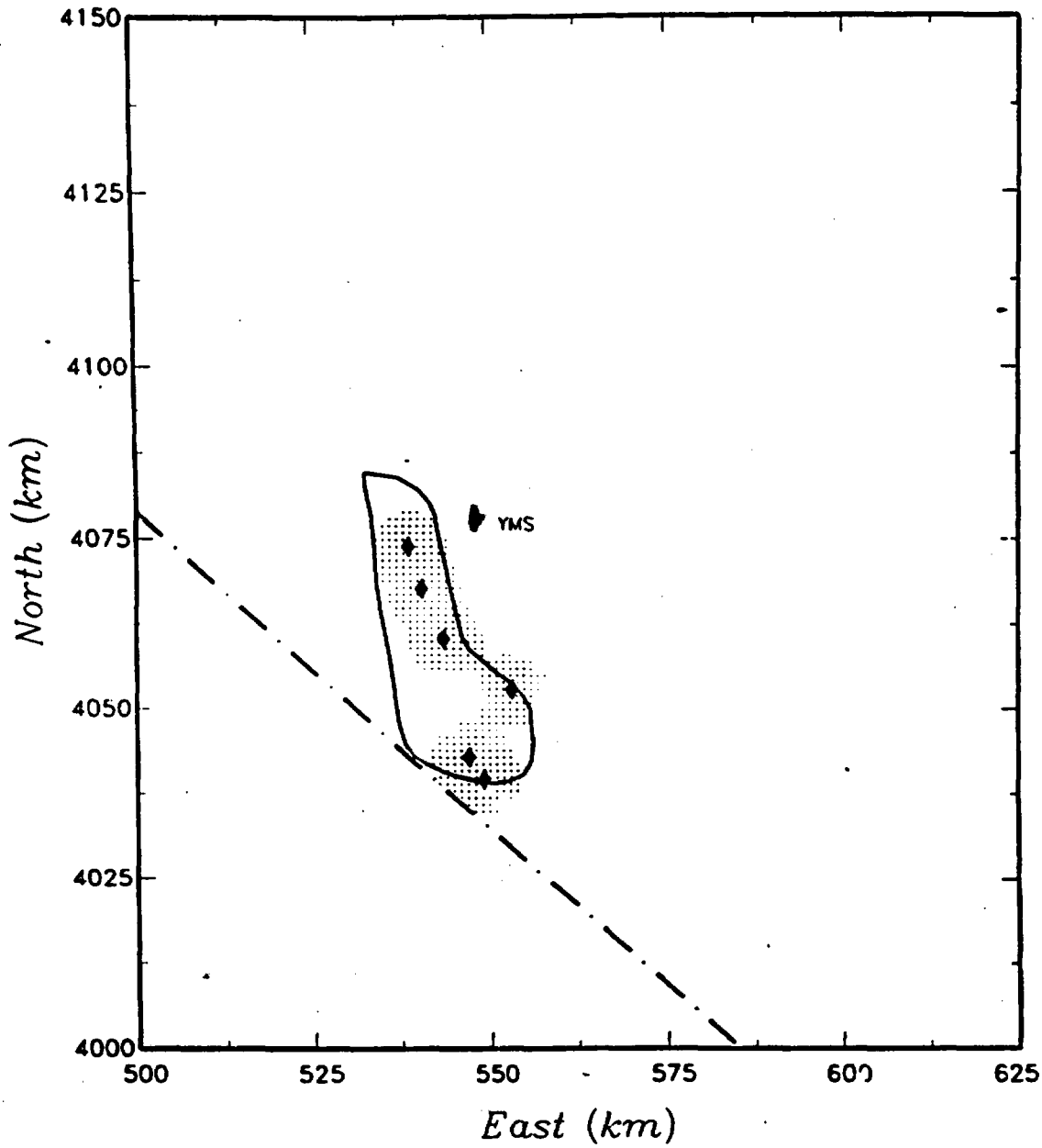


Figure 3-38 Example of a kernel density estimate based on Mel Kuntz's preferred event counts for the post-5 Ma time period (shown by diamonds) and Zone C (Crater Flat) representing an approximation of the 90-percent density contour (the stippled area). The resulting Gaussian kernel smoothing parameter, *h*, is 2.8 km. YMS refers to the proposed Yucca Mountain repository site and the dash-dot line is the Nevada-California border.

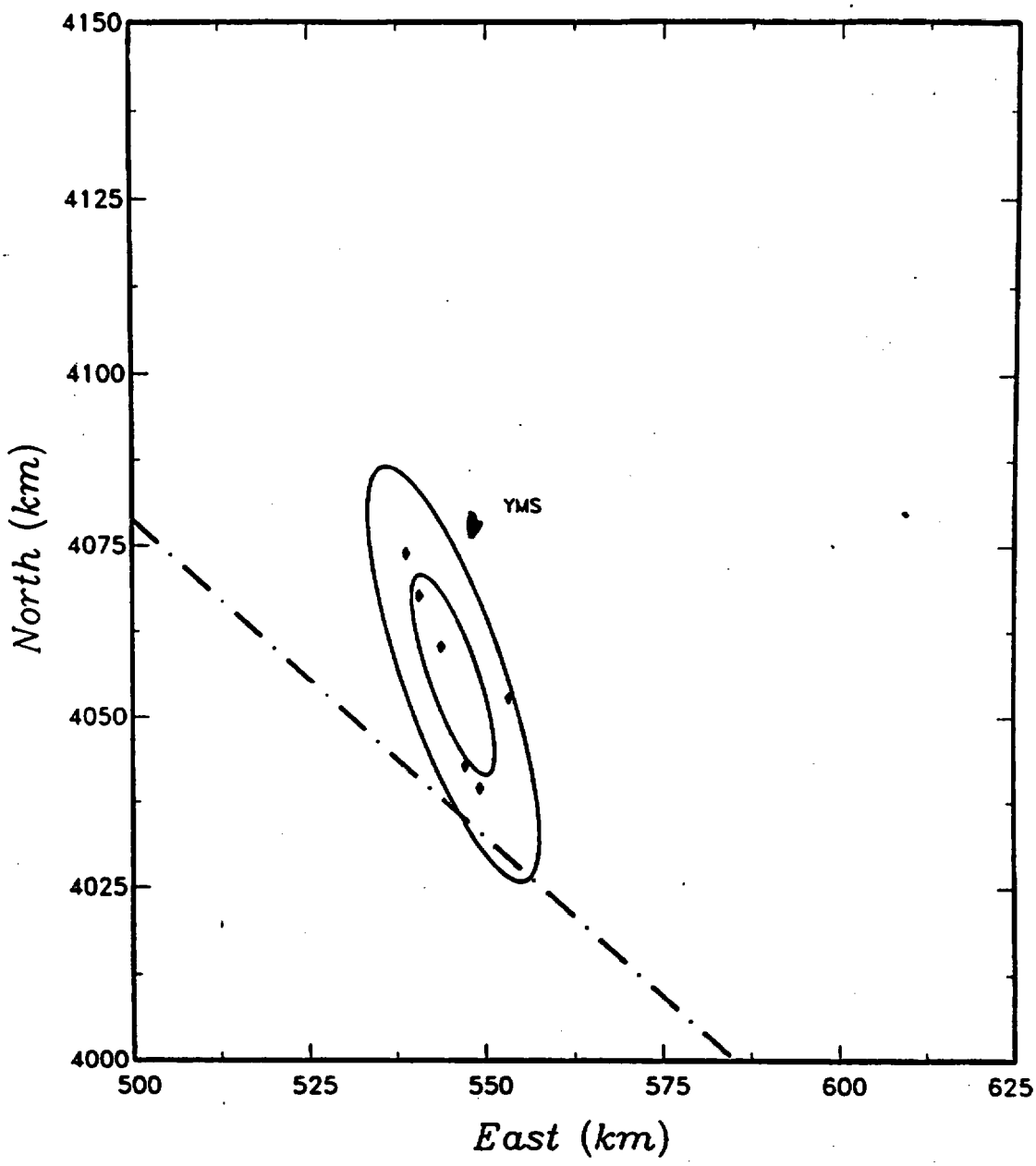


Figure 3-39 Example of the fit of a Gaussian field to Mel Kuntz's preferred event counts for the post-5 Ma time period (shown by diamonds) in Zone C (Crater Flat). The 50th and 95th percentile density contours are shown. YMS refers to the proposed Yucca Mountain repository site and the dash-dot line is the Nevada-California border.

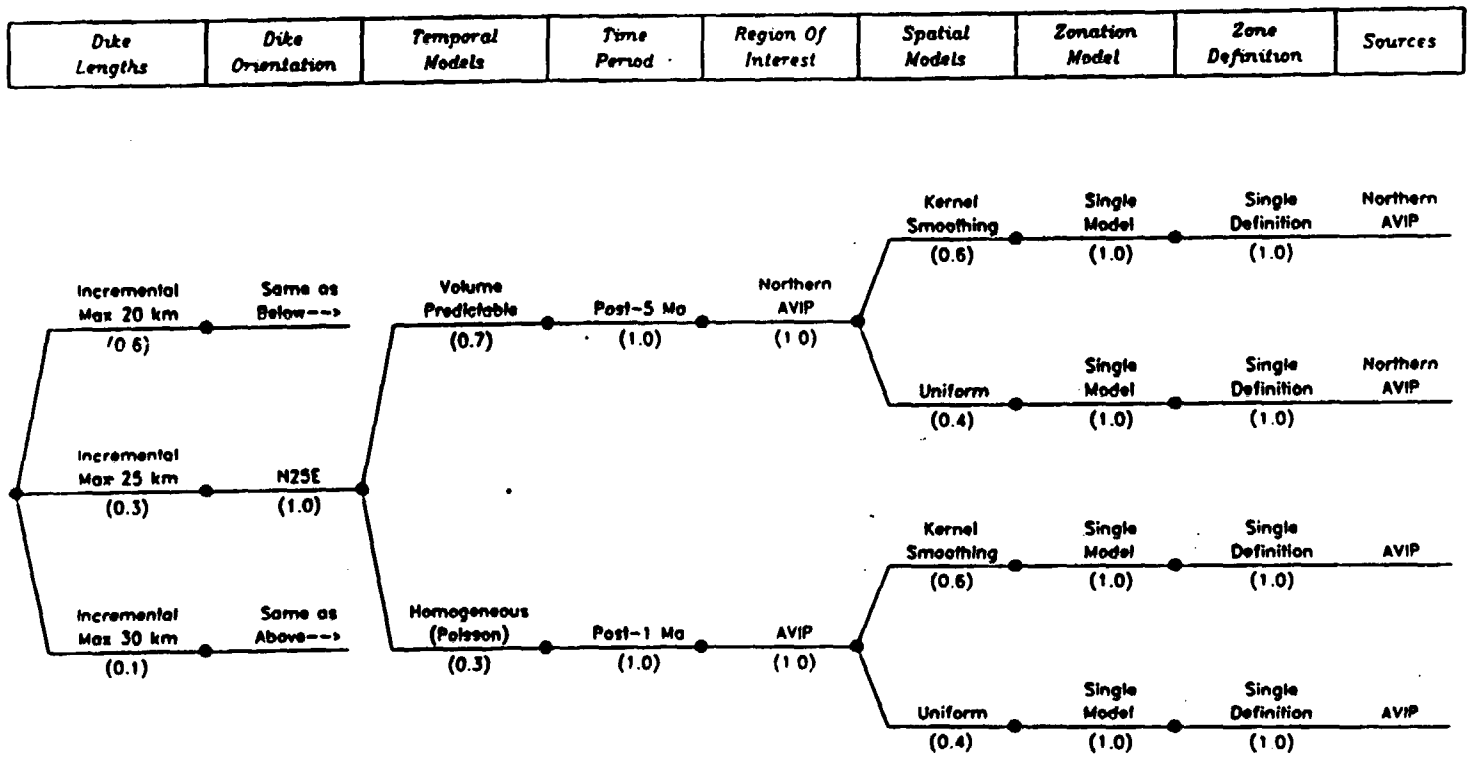


Figure 3-44 Logic tree for the PVHA model developed by Richard Carlson.

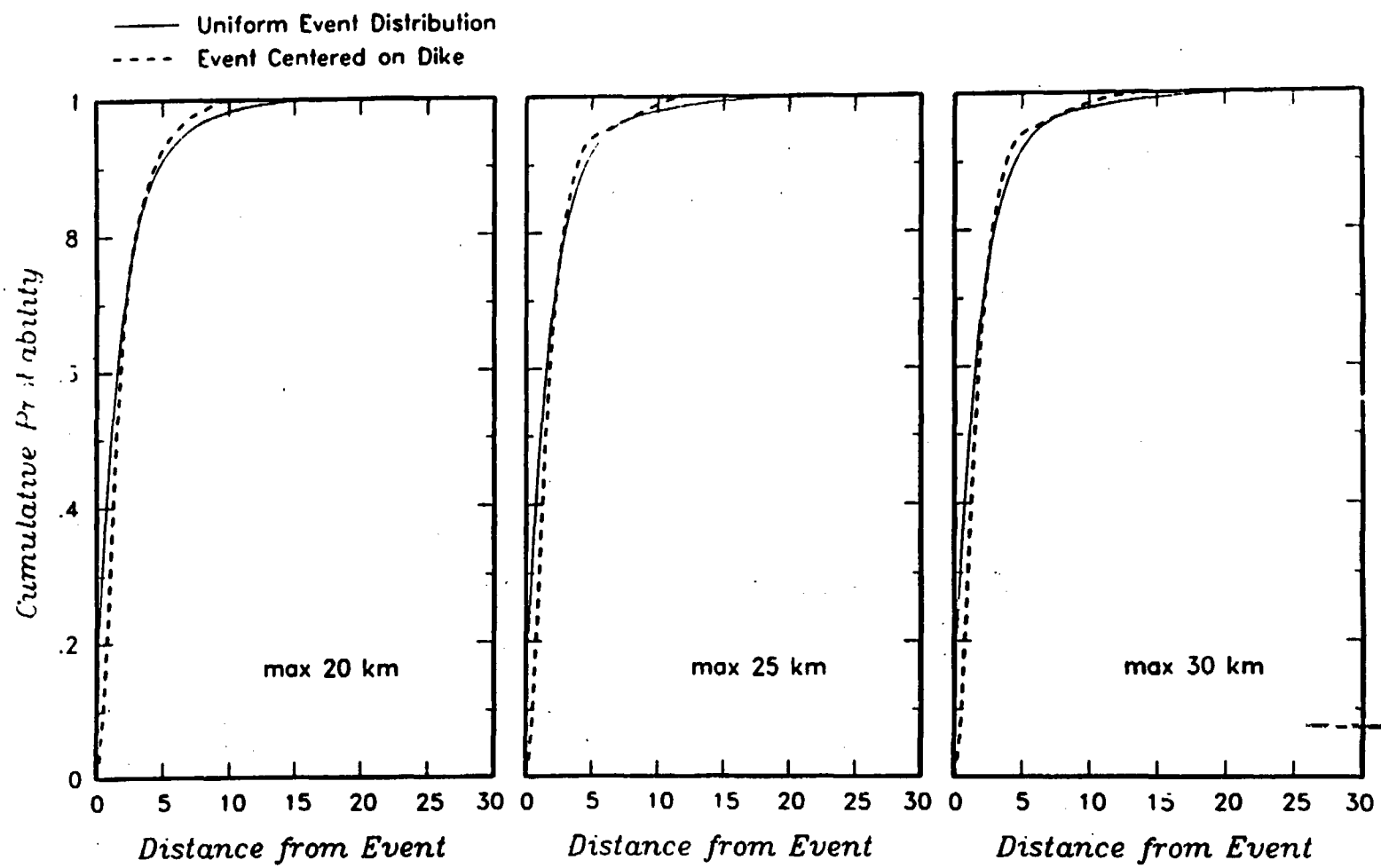


Figure 3-45 Alternative distributions for the length of an *f(l)* developed from the assessments by Richard Carlson.

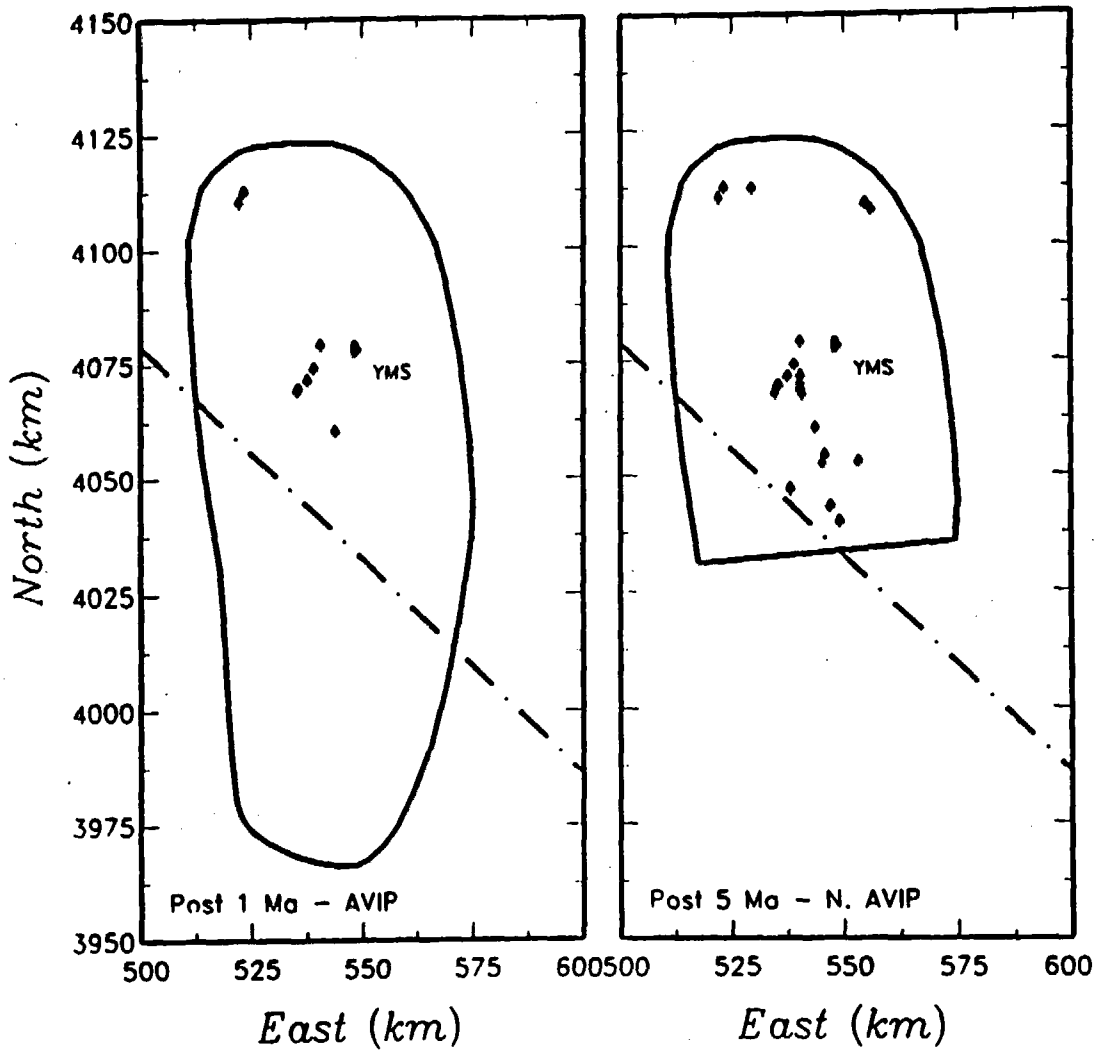


Figure 3-46 Regions of interest specified by Richard Carlson. Diamonds represent volcanic events for the post-1 Ma and the post-5 Ma time periods. YMS refers to the proposed Yucca Mountain repository site and the dash-dot line is the Nevada-California border.

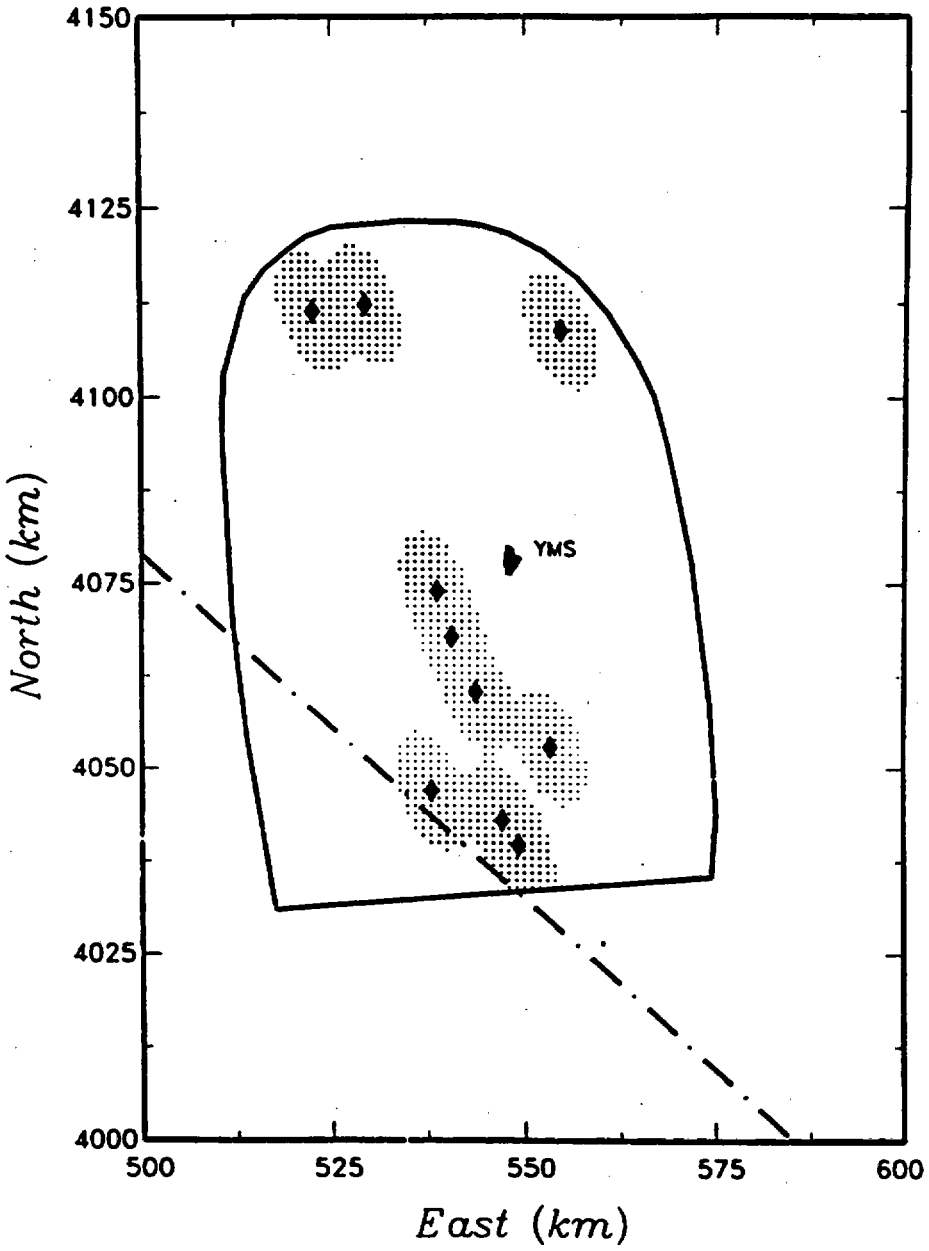


Figure 3-47 Example of the fit of an Epanechnikov kernel with a 2:1 aspect ratio and *h* for the major axis of 10 km to Richard Carlson's preferred event counts for the northern AVIP region and the post-5 Ma time period. The stippled area outlines the 95th percentile density contour. YMS refers to the proposed Yucca Mountain repository site and the dash-dot line is the Nevada-California border.

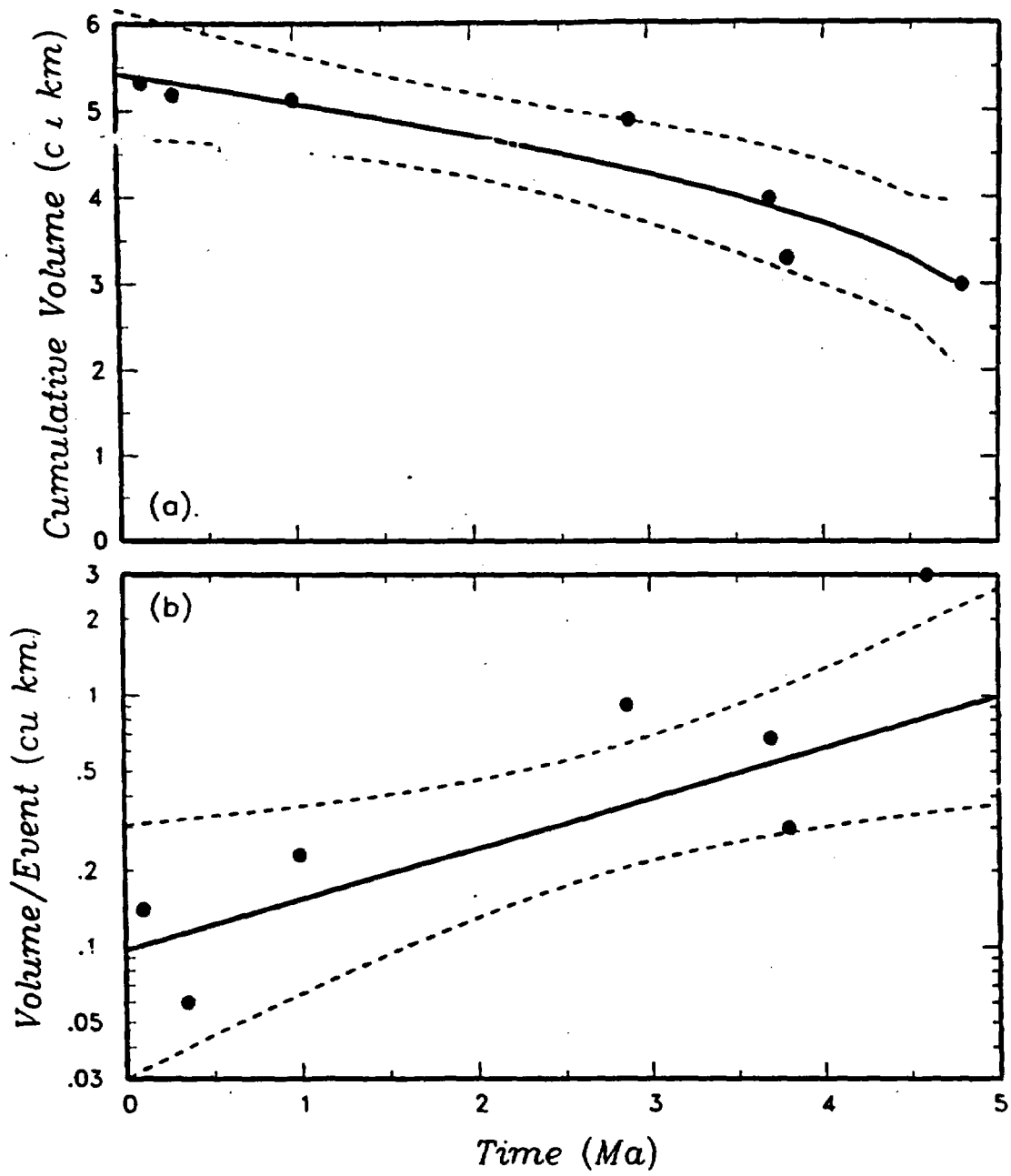


Figure 3-48 Parameters for the volume predictable rate model used by Richard Carlson. (a) Relationship for cumulative volume $V_M(t)$. (b) Example of relationship for volume per event, $V_E(t)$ computed for the most likely event counts in the northern AVIP zone.

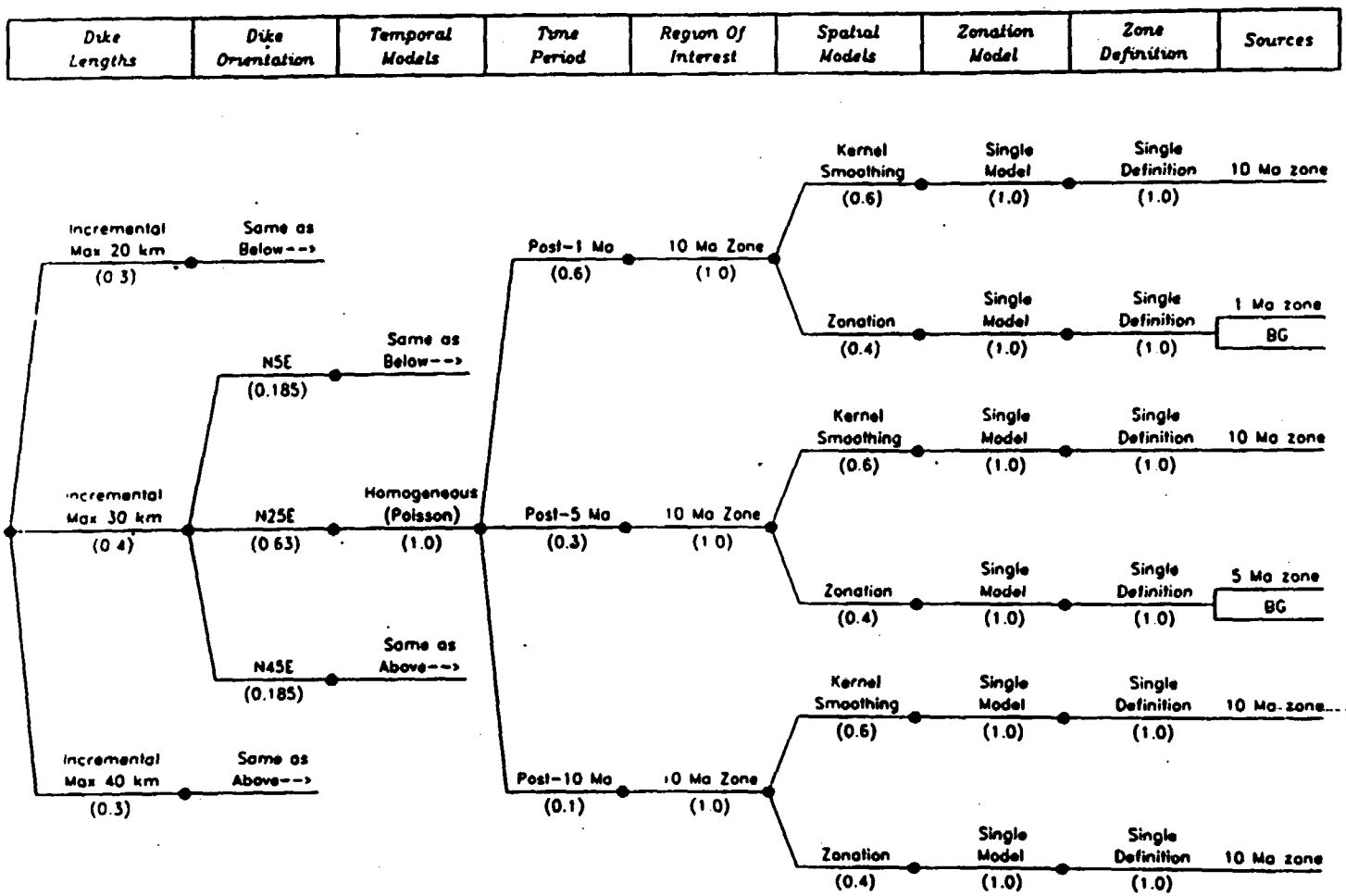


Figure 3-58 Logic tree for the PVH('el developed by William Hackett.

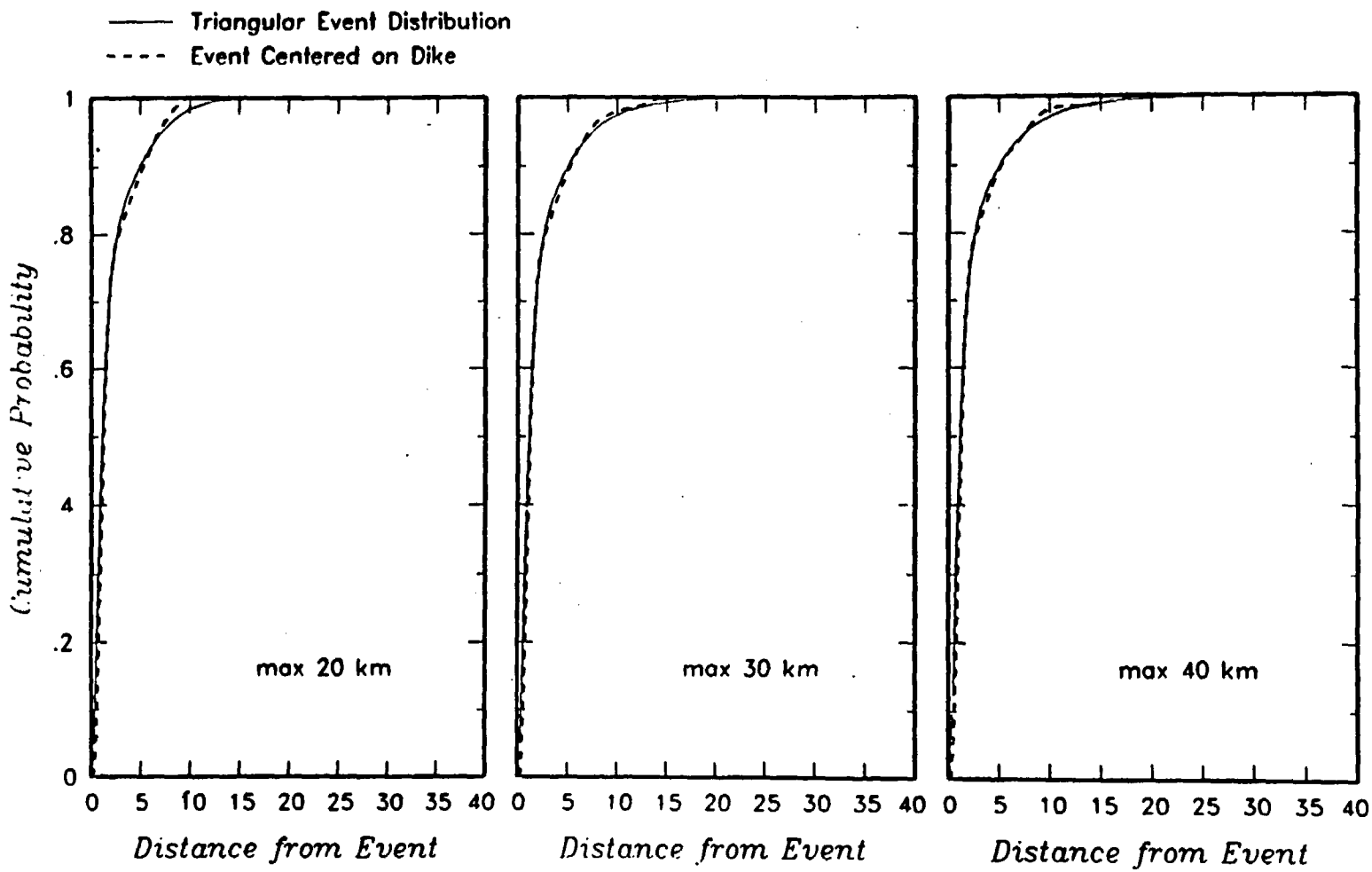


Figure 3-59 Alternative distributions for the length of an event *f(l)* developed from the assessments by William Hackett.

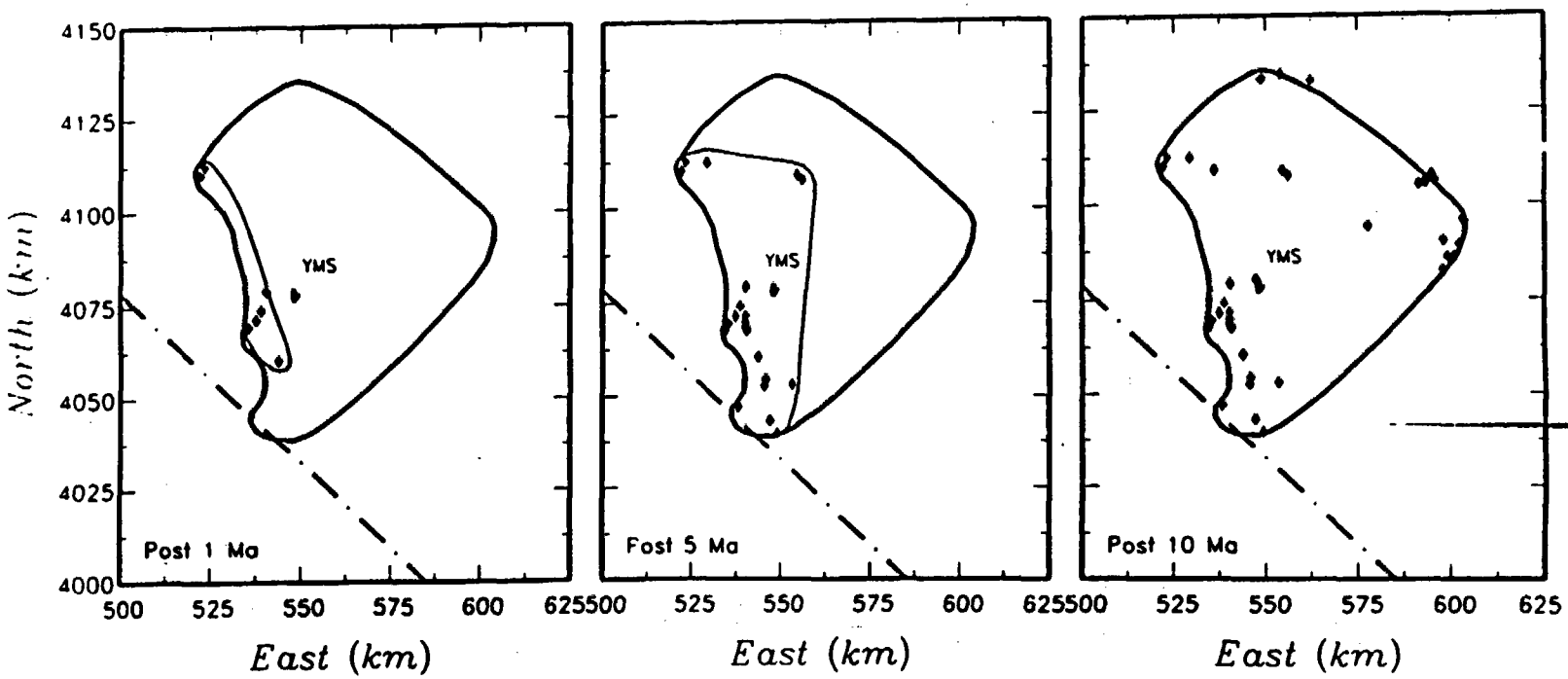


Figure 3-60 Region of interest and source zones [illegible]d by William Hackett.. Diamonds represent volcanic events for the indicated time periods. YMS refe[illegible] the proposed Yucca Mountain repository site and the dash-dot line

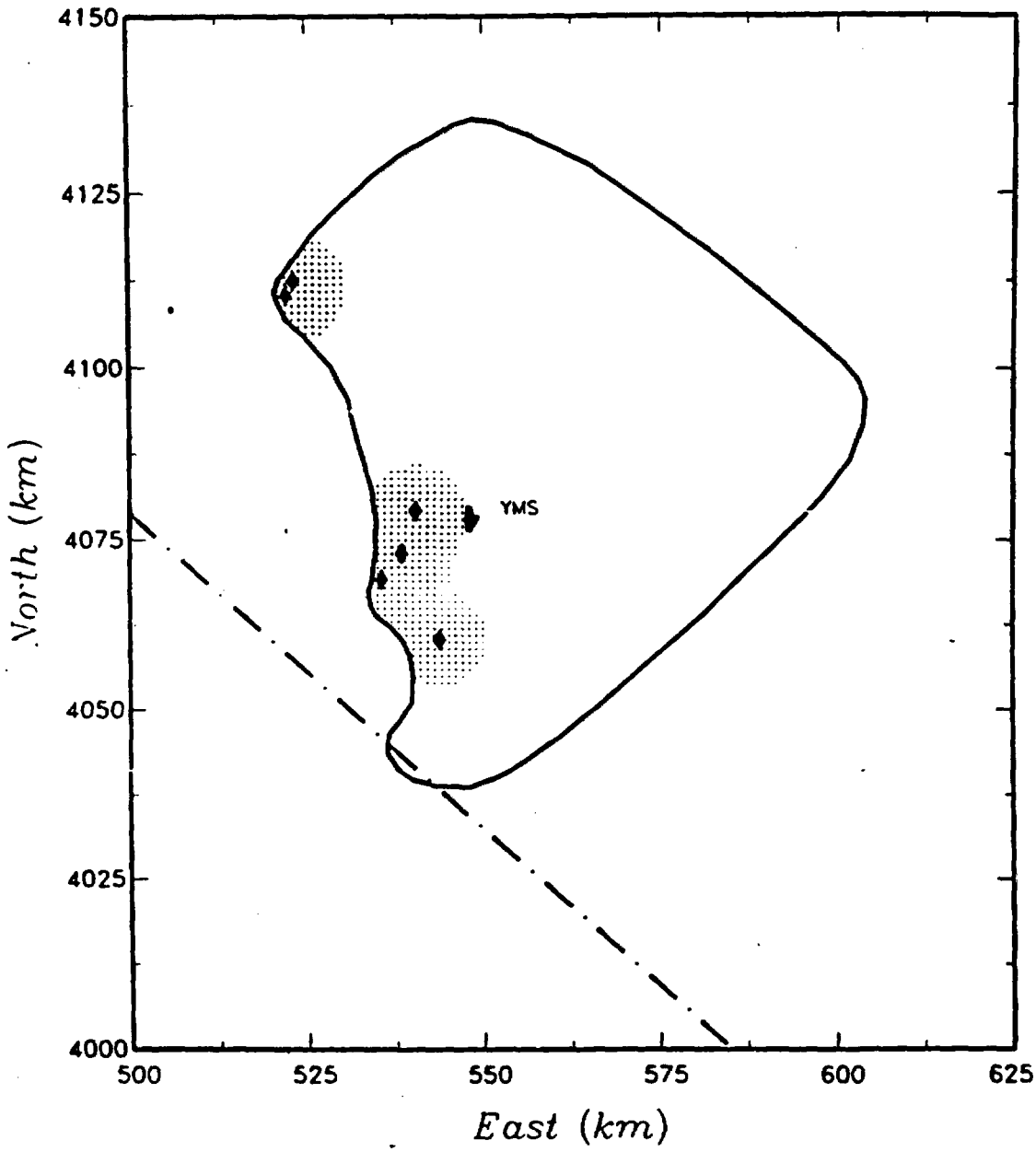
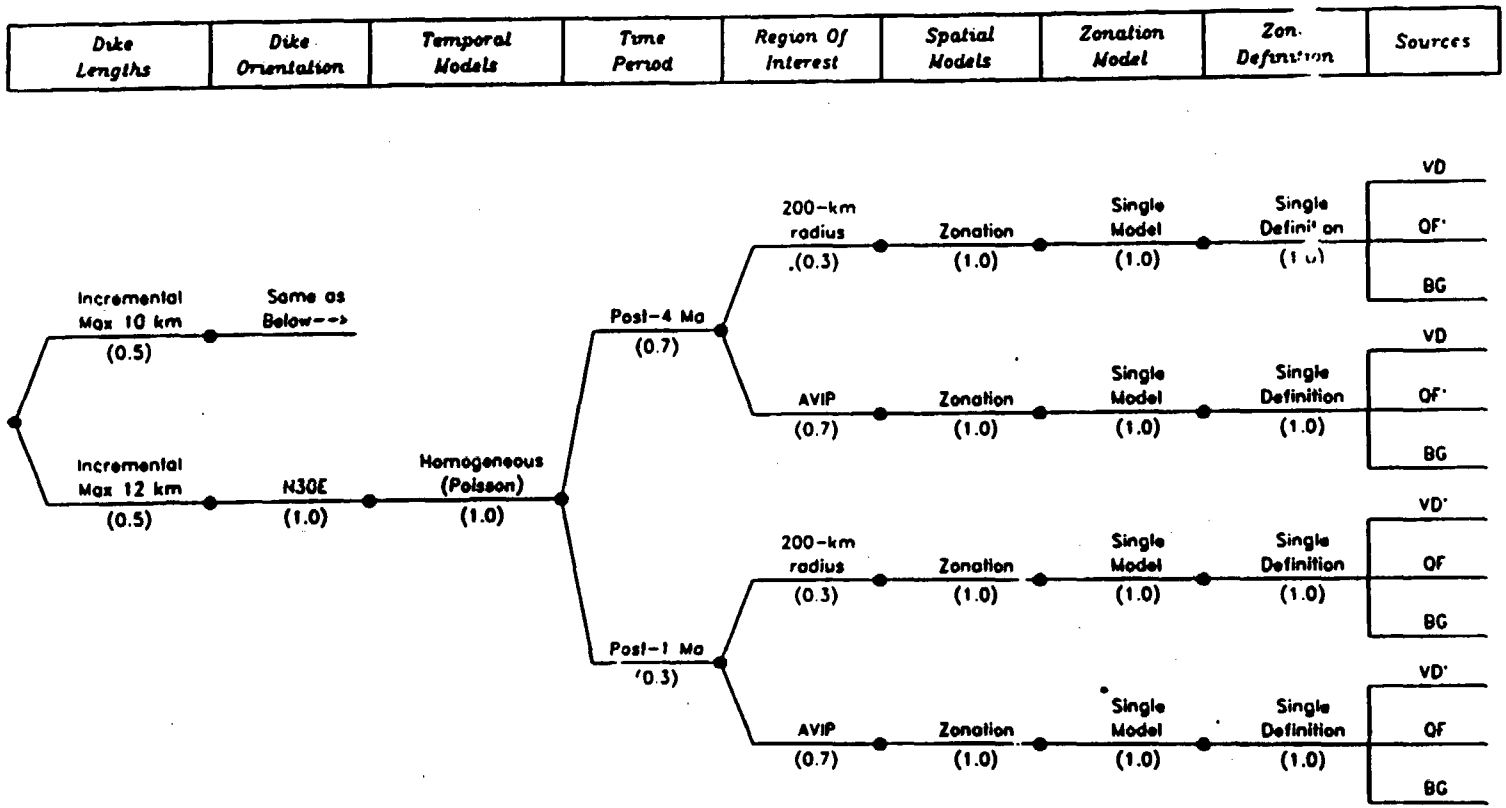


Figure 3-61 Example of the fit of a Gaussian kernel with h equal to 3.2 km to William Hackett's preferred event counts for the post-1 Ma time period. The stippled area outlines the 95th percentile density contour. YMS refers to the proposed Yucca Mountain repository site and the dash-dot line is the Nevada-California border.



VD: Volcanic Domain
QF: Quaternary Faulting Domain
VD': Volcanic Domain Outside of Quaternary Faulting Domain
QF': Quaternary Faulting Domain Outside of Volcanic Domain
BG: Background

Figure 3-26 Logic tree for the PVHA model developed by George Thompson.

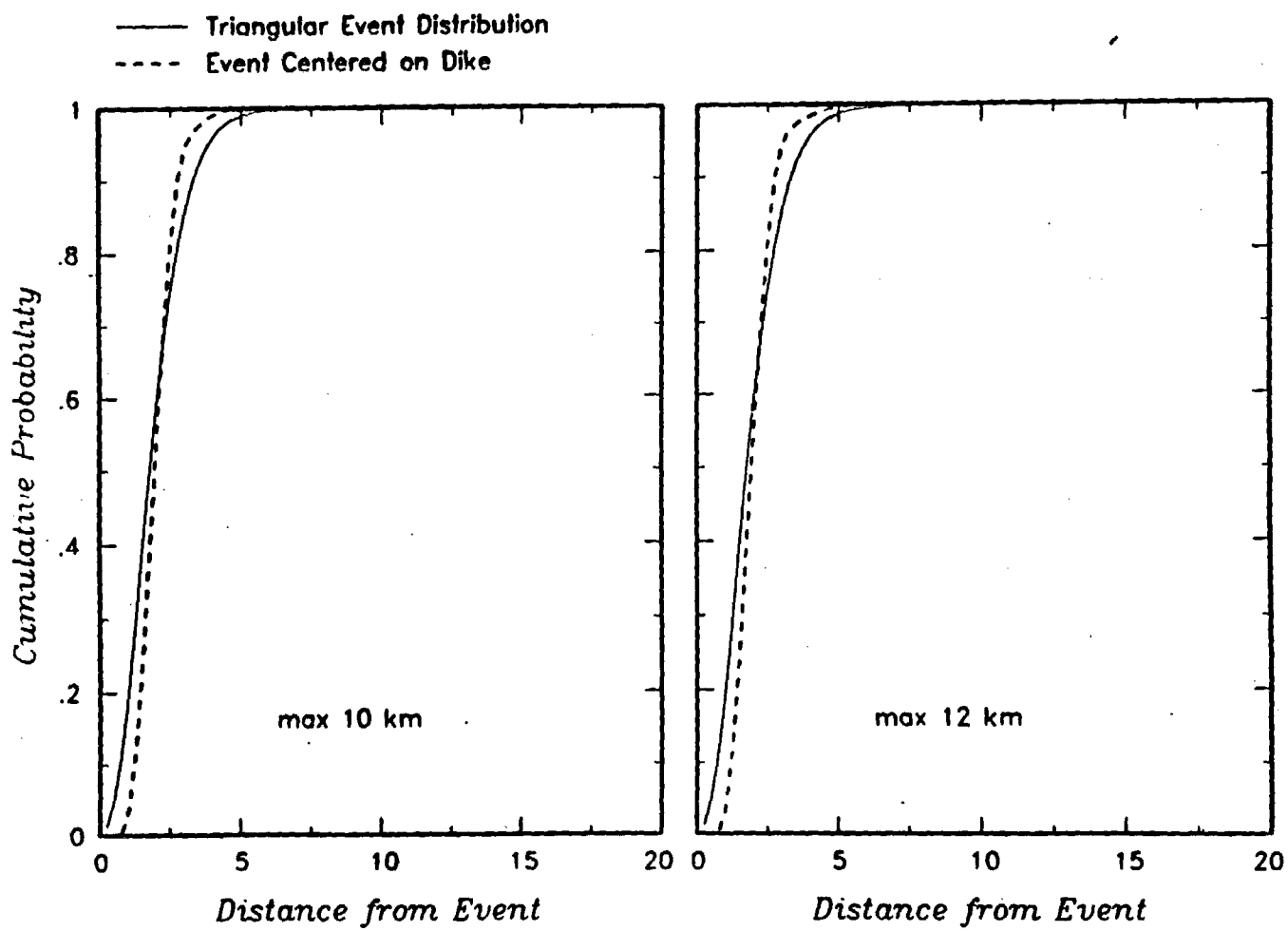


Figure 3-27 Alternative distributions for the length of an event *f(l)* developed from the assessments by George Thompson.

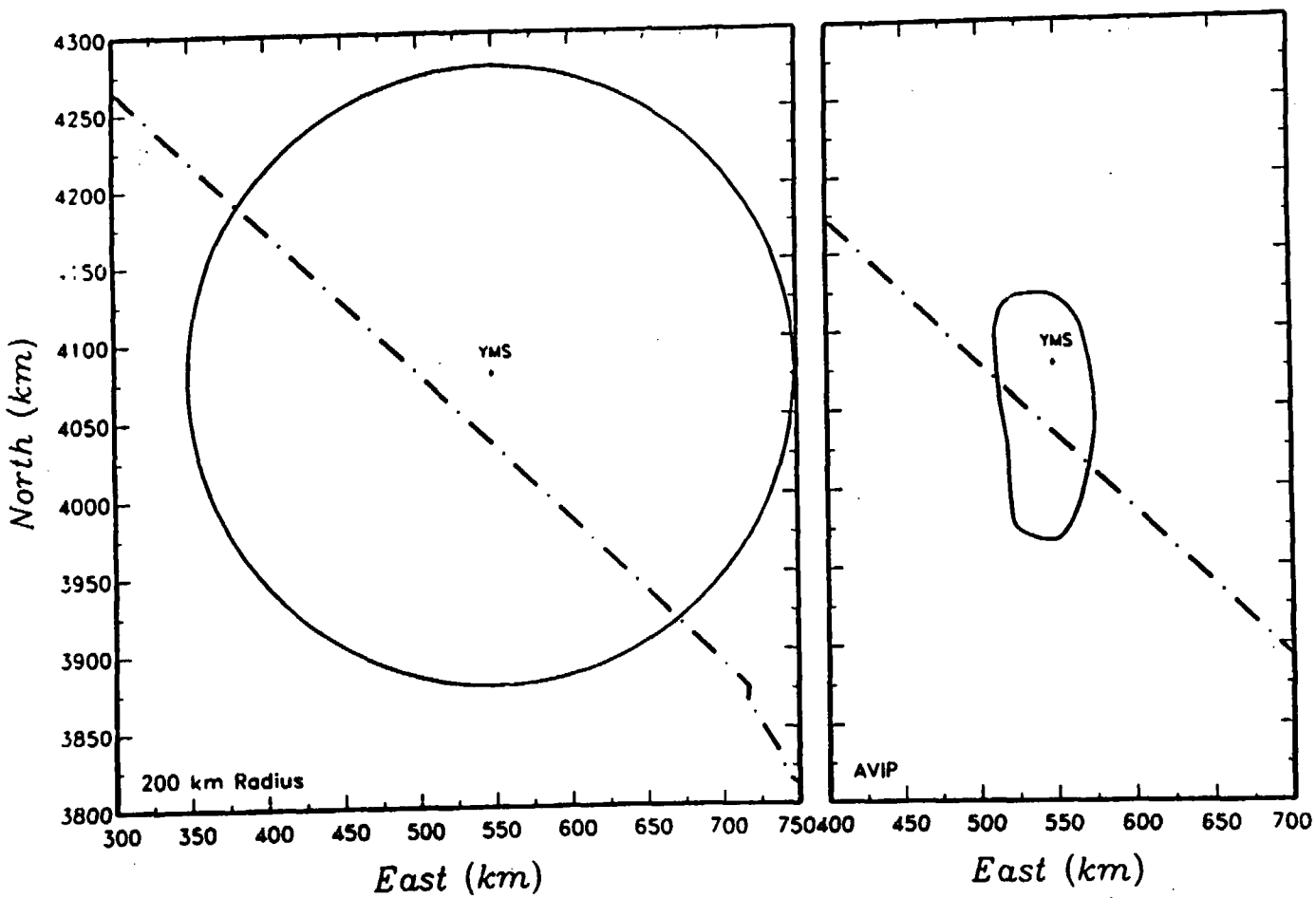


Figure 3-28 Alternative regions of interest used as background source zones in George Thompson's PVHA model. YMS refers to the proposed Yucca Mountain repository site and the dash-dot line is the Nevada-California border.

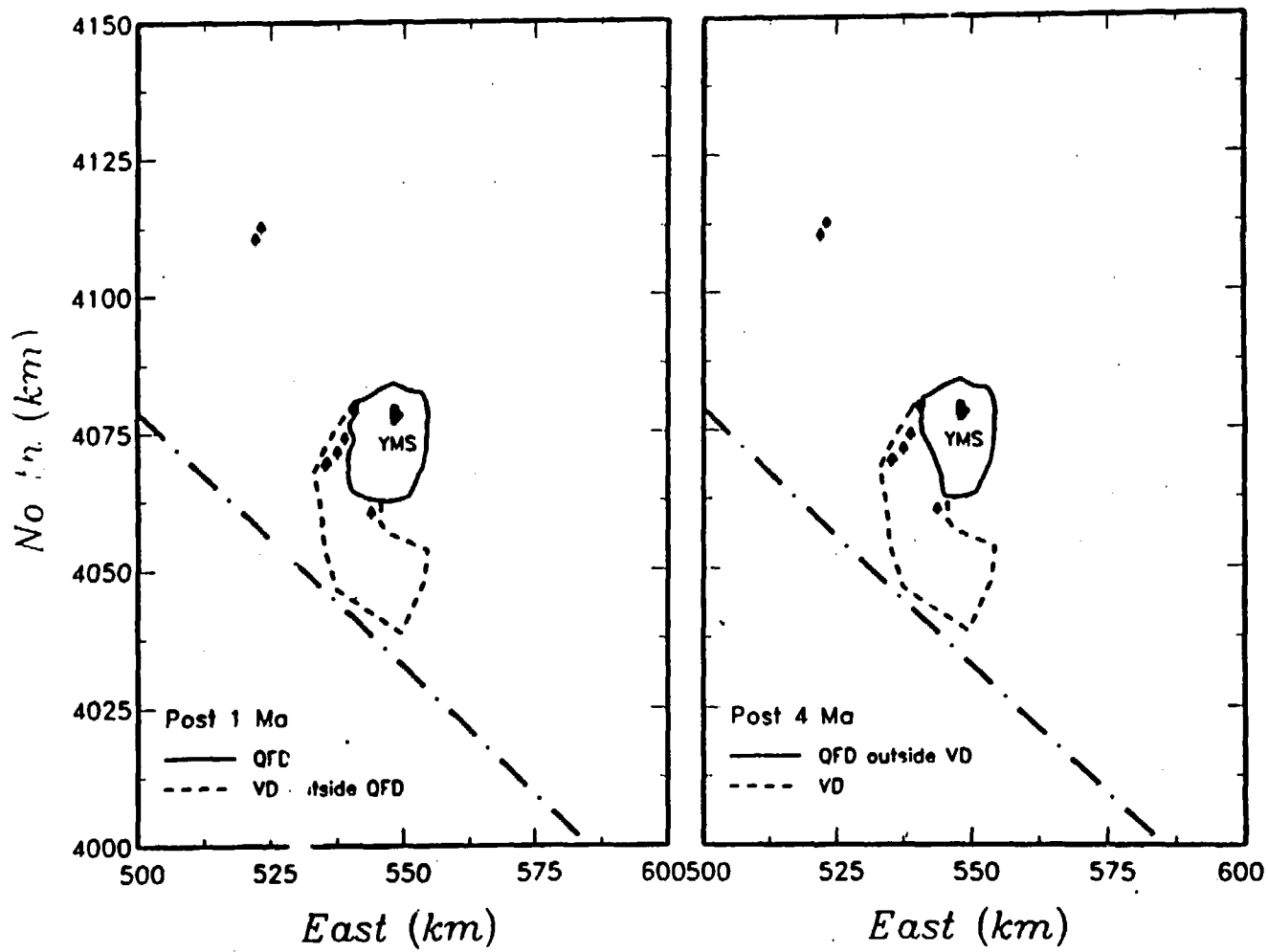
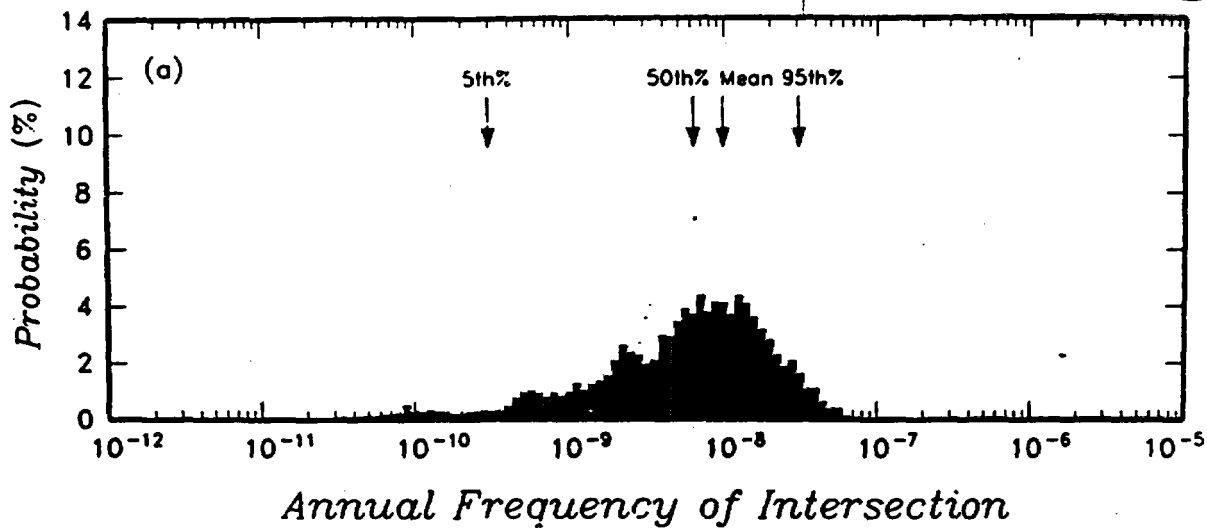


Figure 3-29 Alternative source zones defined by George Thompson. Diamonds represent volcanic events for the post-1 Ma and post-4 Ma time periods. YMS refers to the proposed Yucca Mountain repository site and the dash-dot line is the Nevada-California border.



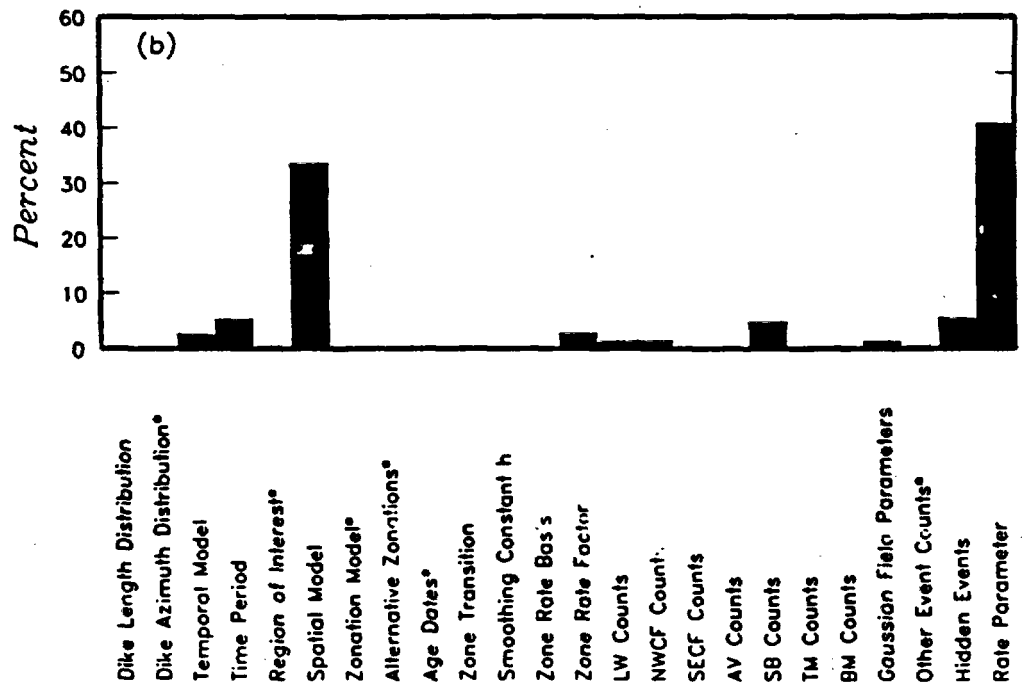


Figure 4-11 PVHA results obtained using Mel Kuntz's PVHA model. (a) Distribution for annual frequency of exceedance. (b) Relative contribution of uncertainty in various components of the PVHA model to the total variance in annual frequency of intersection. Components marked with were not treated as uncertain

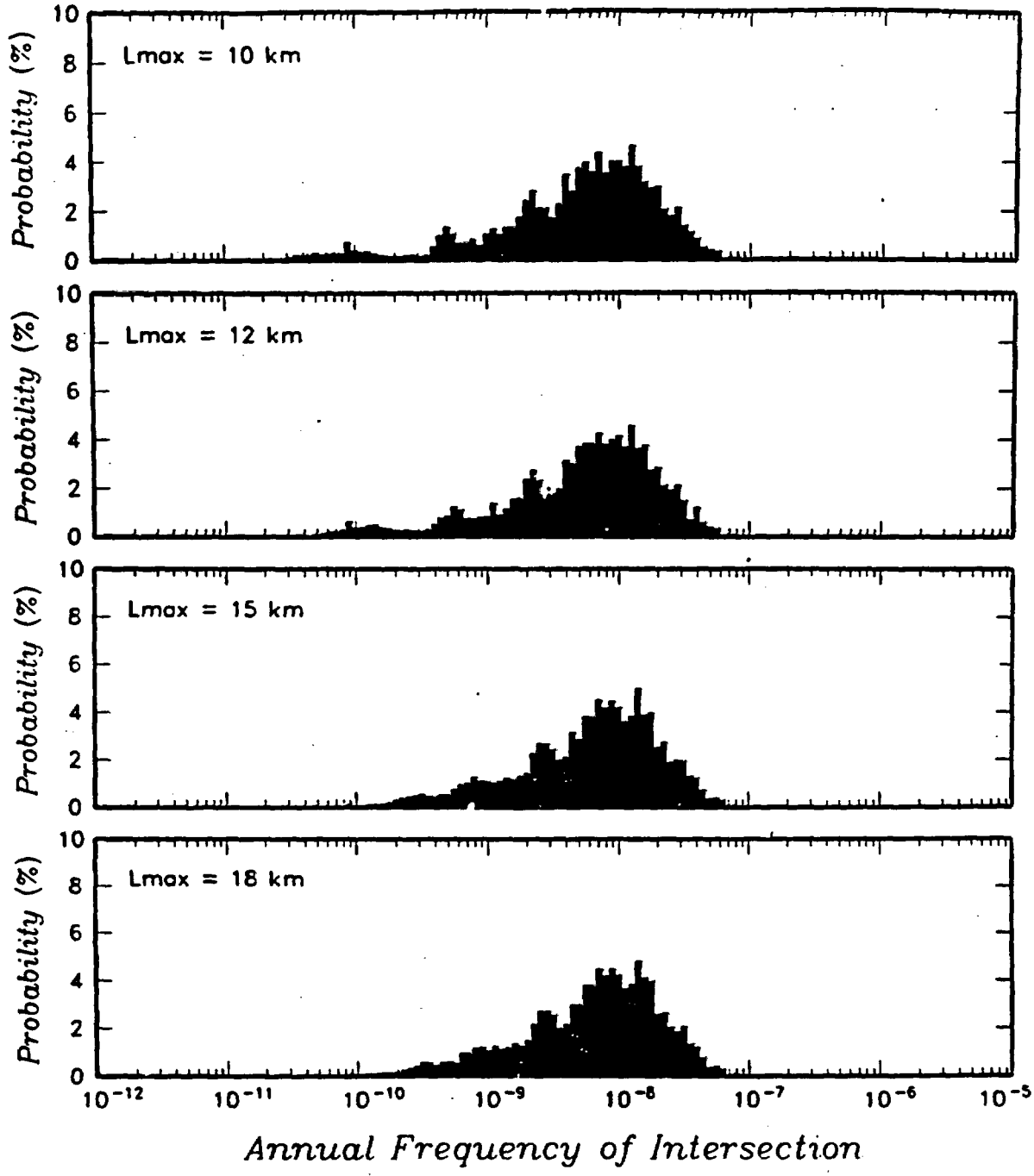


Figure 4-12 Effect of choice of maximum dike length on computed hazard distribution for Mel Kuntz's PVHA model.

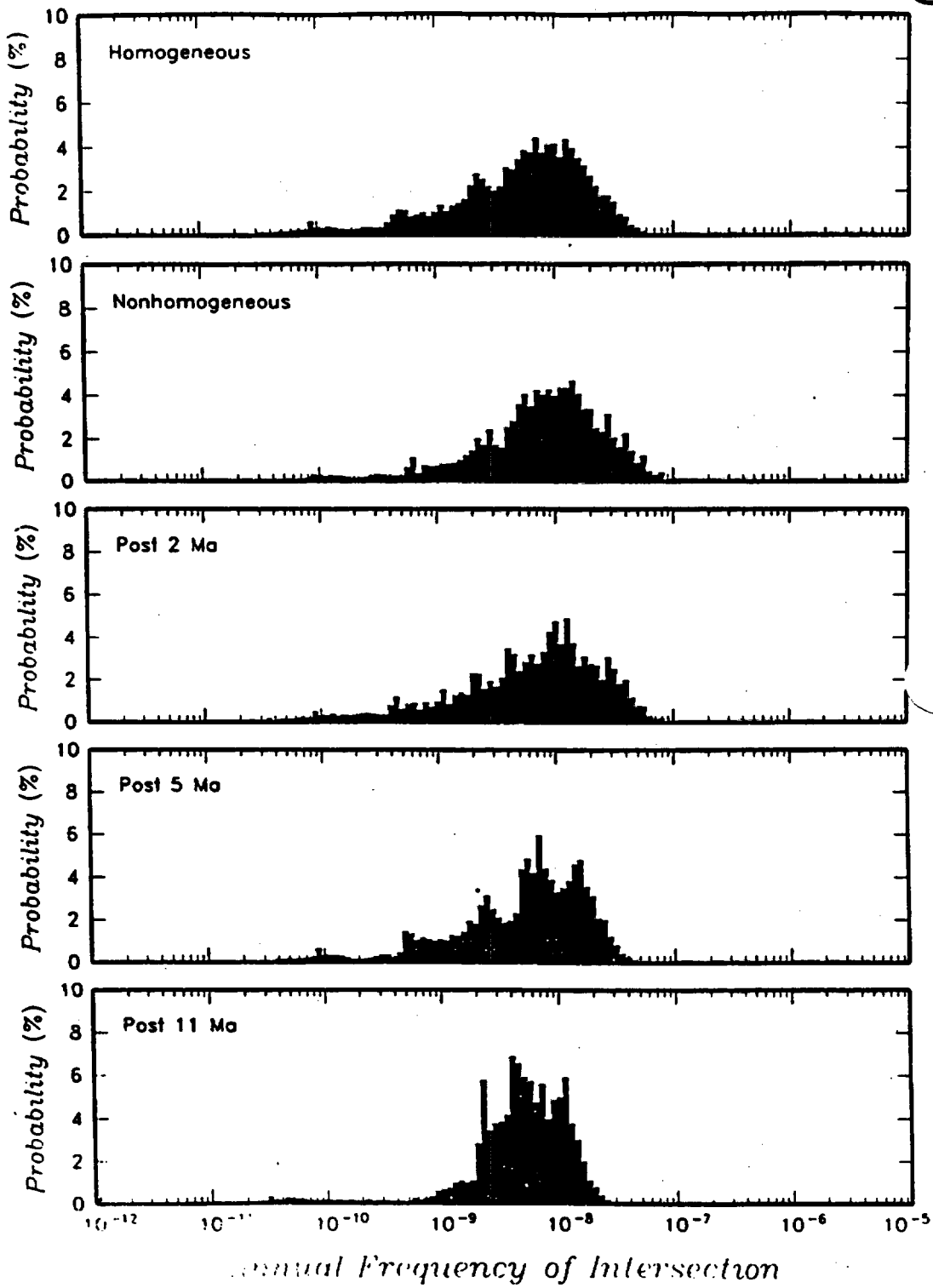


Figure 4-13 Effect of choice of temporal model and time period of interest on computed hazard distribution for Mel Kuntz's PVHA model

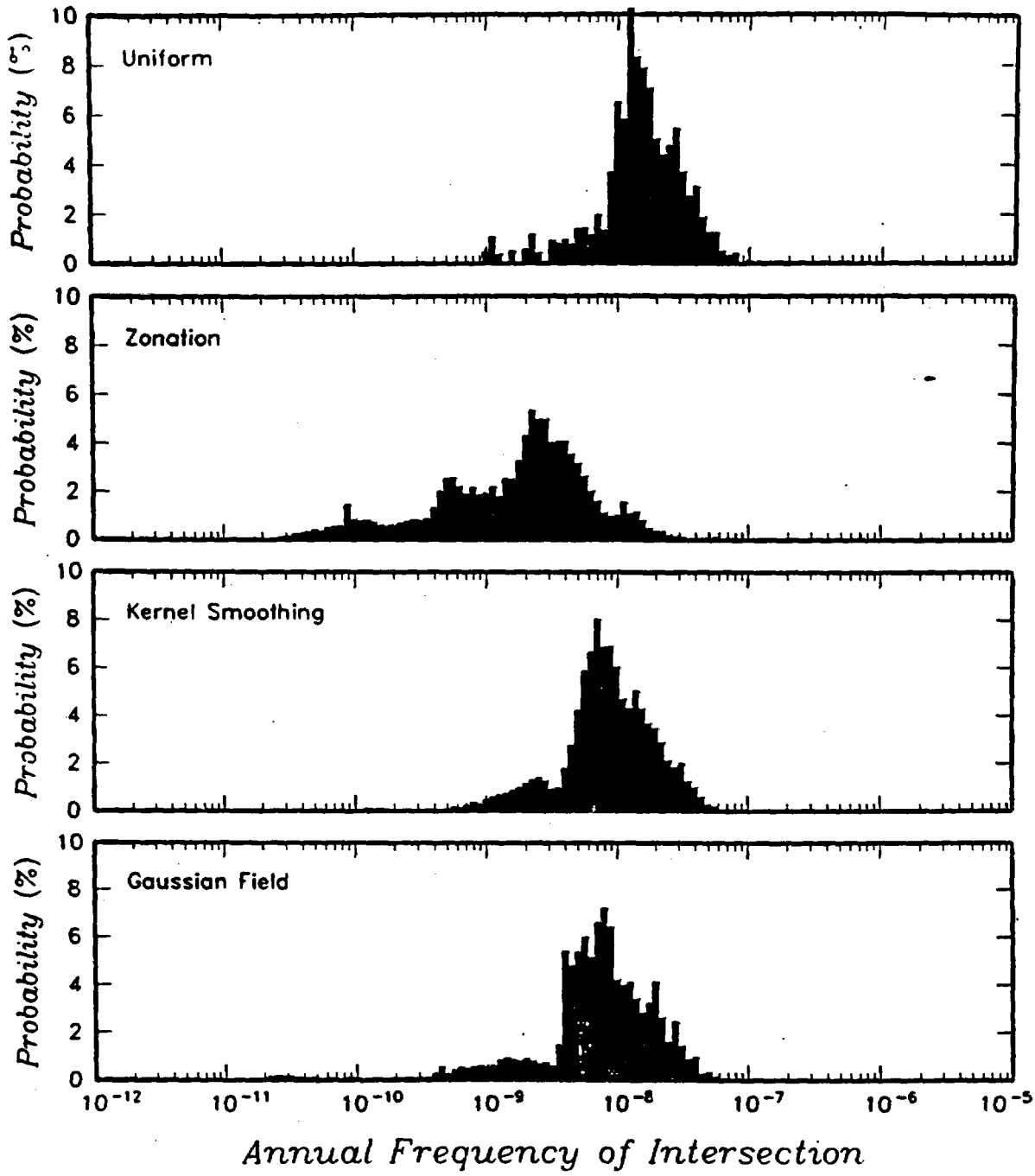
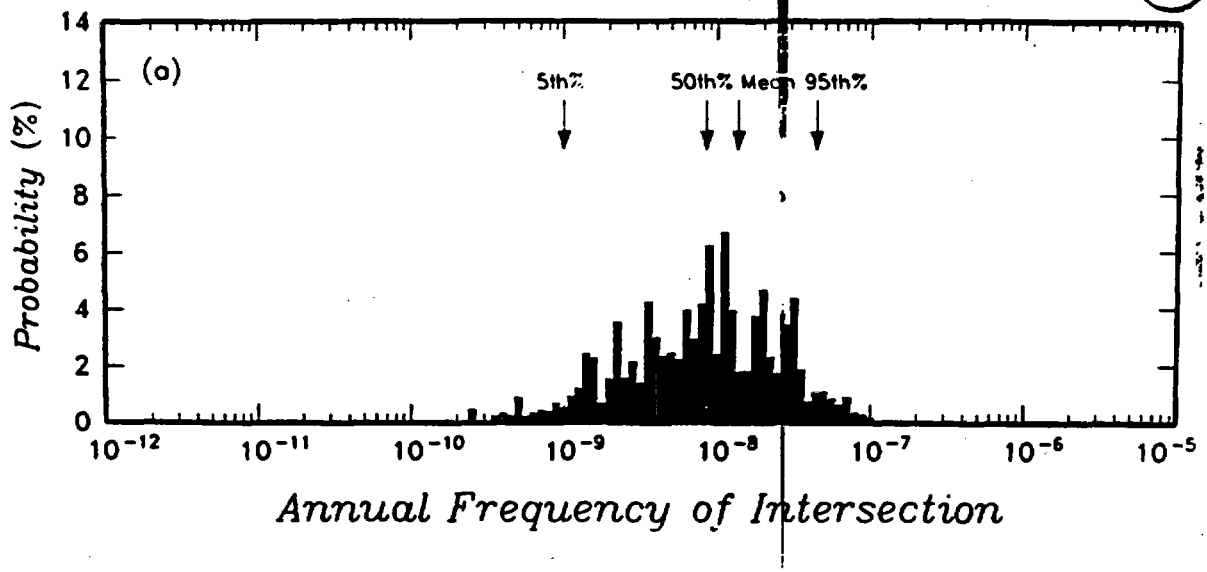


Figure 4-14 Effect of choice of spatial model on computed hazard distribution for Mel Kuntz's PVHA model.



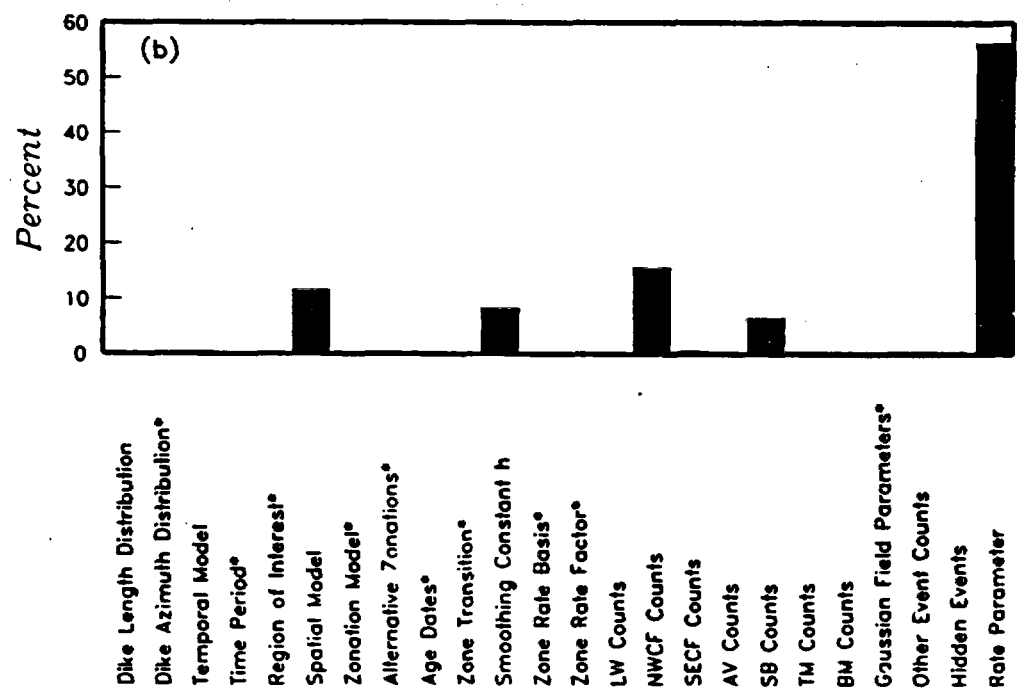


Figure 4-19 PVHA results obtain J using Richard Carlson's PVHA mode . (a) Distribution for annual frequency of exceedar :e (b) Relative contribution of uncertainty in various components of the PVHA model to the total variance in annual frequency of intersection. Components marked with a * were not treated as uncertain.

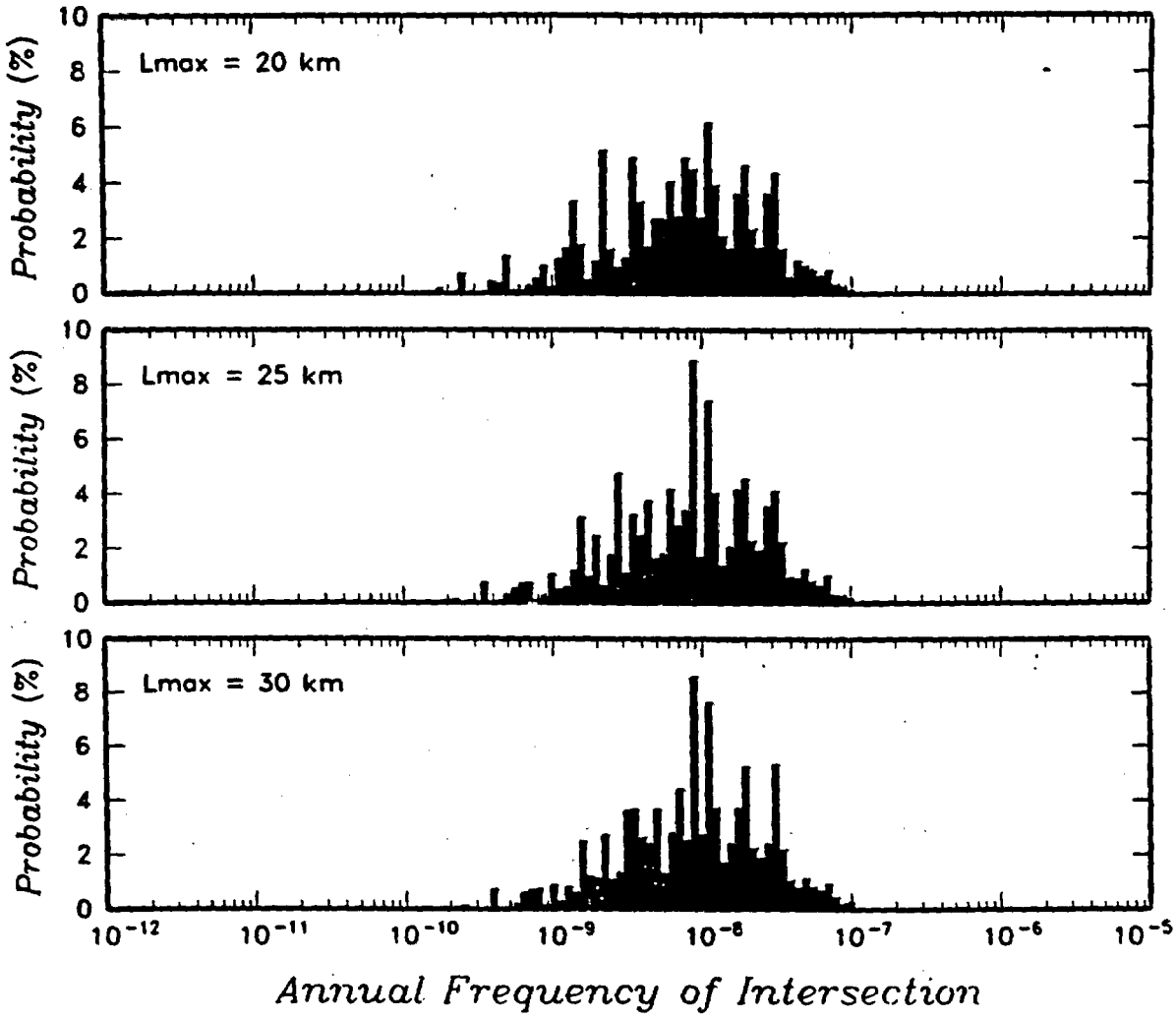


Figure 4-20 Effect of choice of maximum dike length on computed hazard distribution for Richard Carlson's PVHA model.

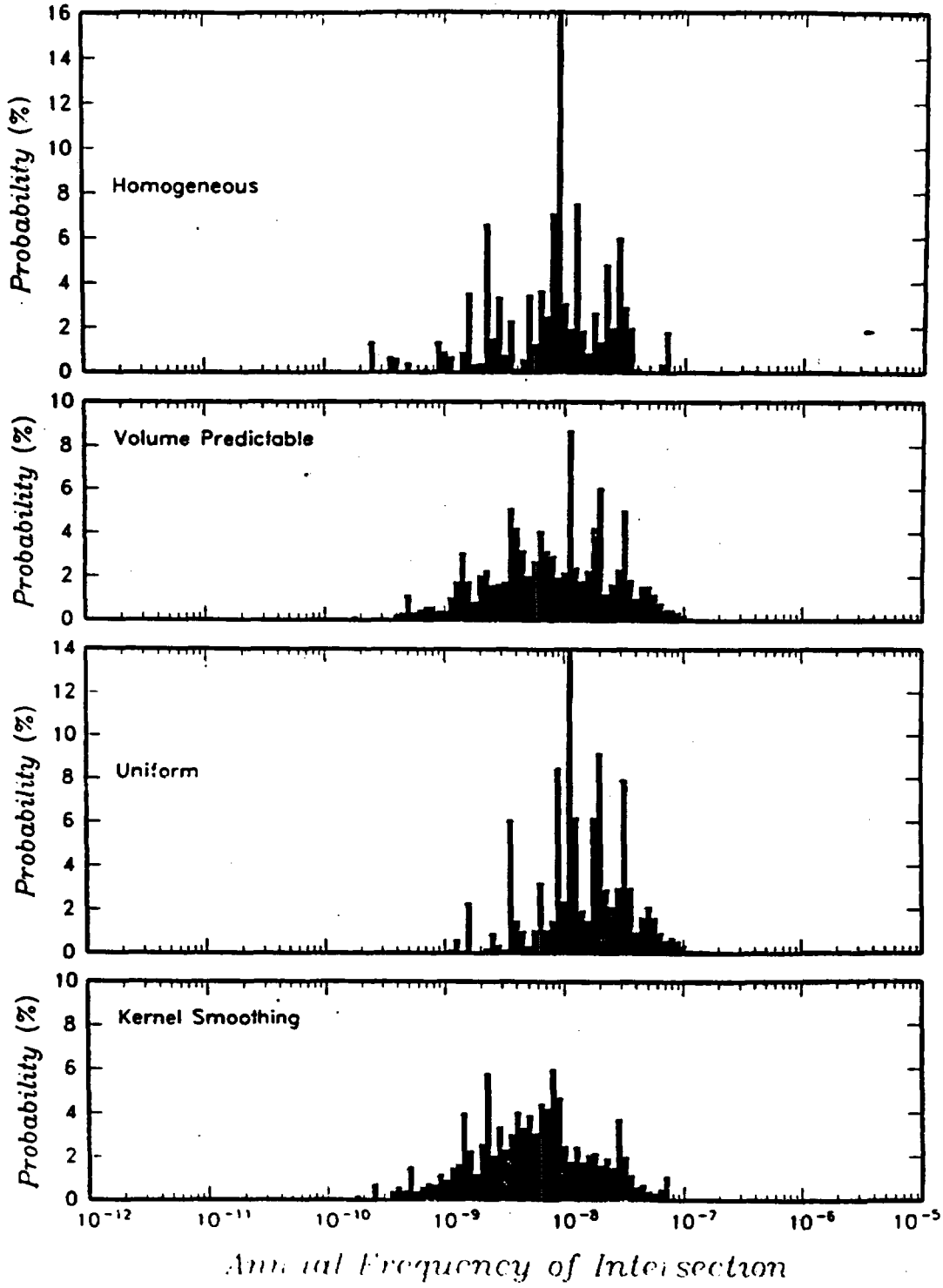
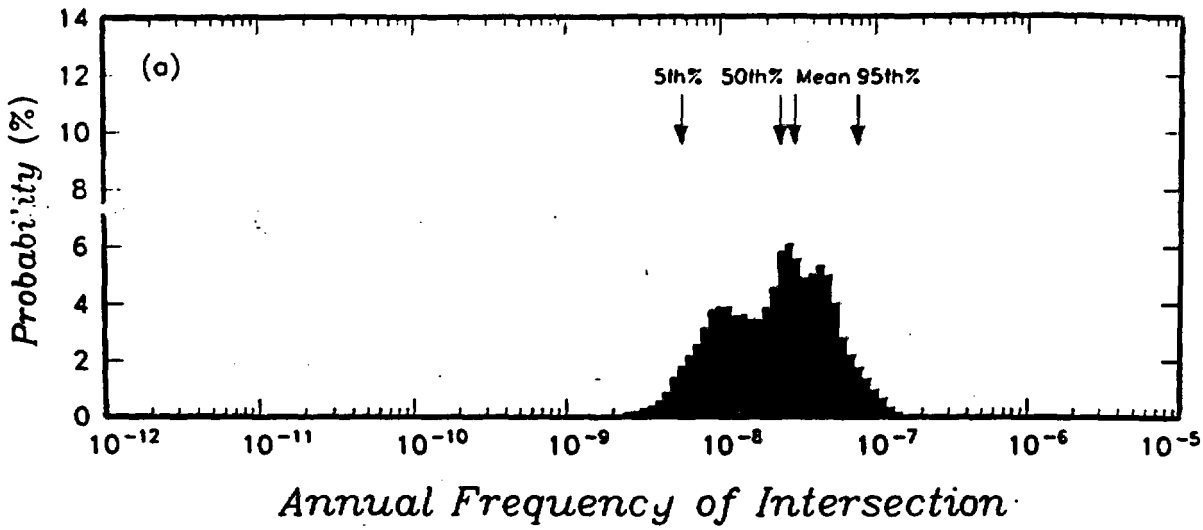


Figure 4-21 Effect of choice of temporal and spatial models on computed hazard distribution for Richard Carlson's PVHA model



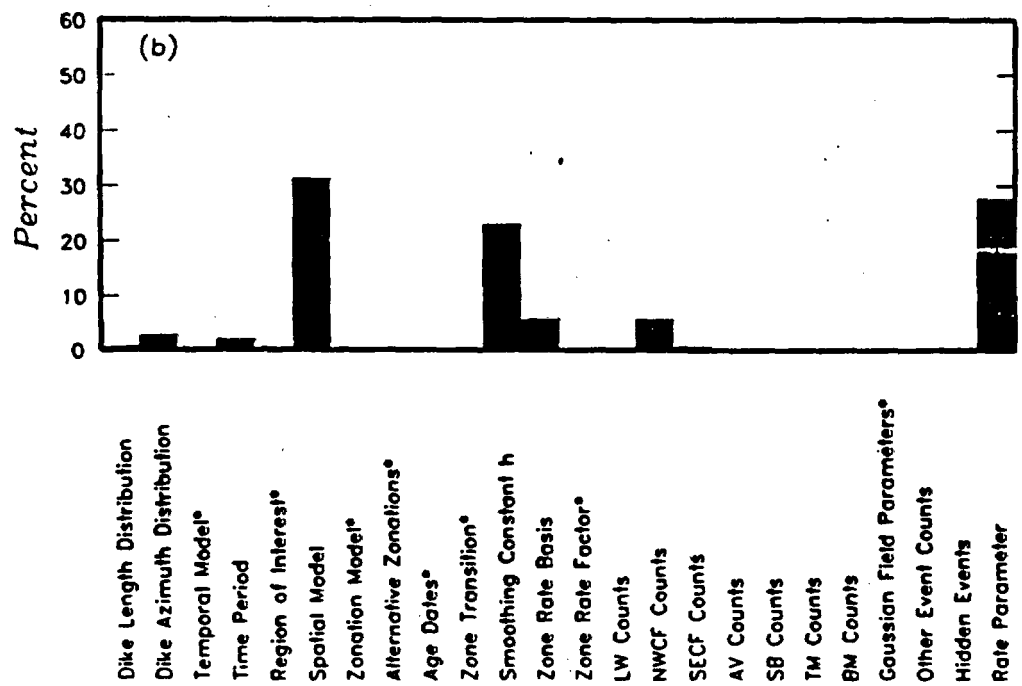


Figure 4-27 PVHA results obtained using William Hackett's PVHA model. (a) Distribution for annual frequency of exceedance. (b) Relative contribution of uncertainty in various components of the PVHA model to the total variance in annual frequency of intersection. Components marked with a * were not treated as uncertain

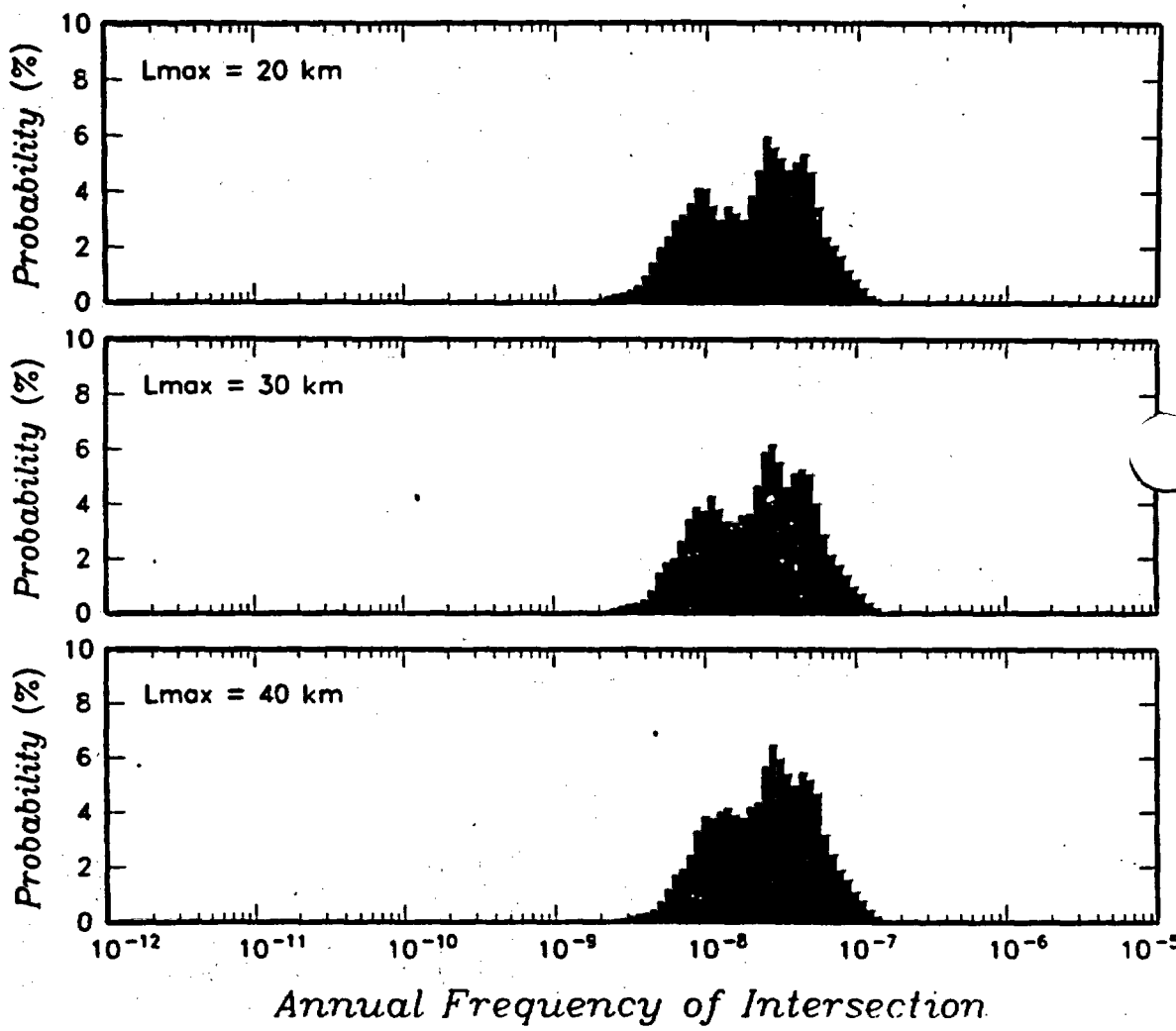


Figure 4-28 Effect of choice of maximum dike length on computed hazard distribution for William Hackett's PVHA model

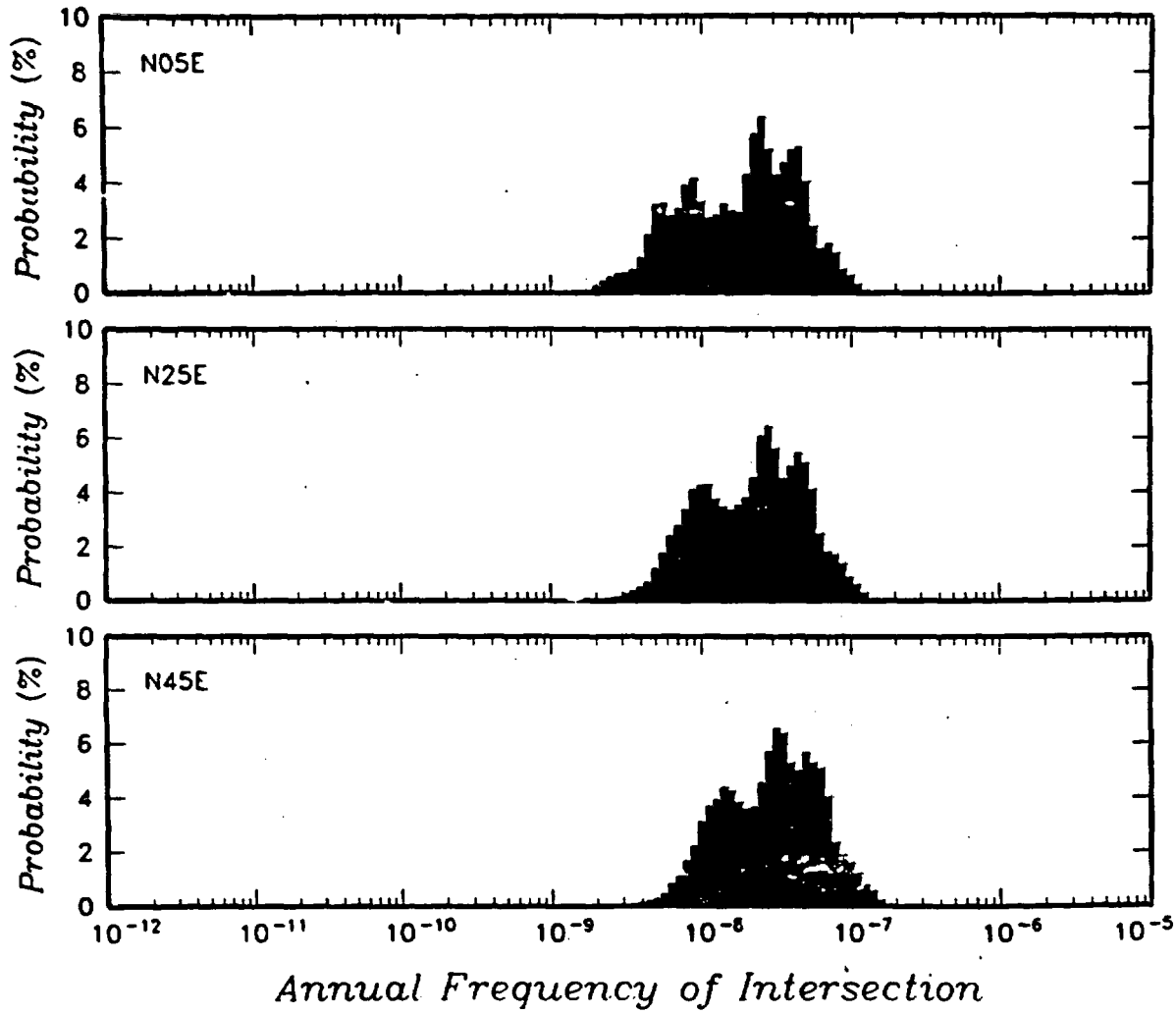


Figure 4-29 Effect of choice of mean dike azimuth on computed hazard distribution for William Hackett's PVHA model

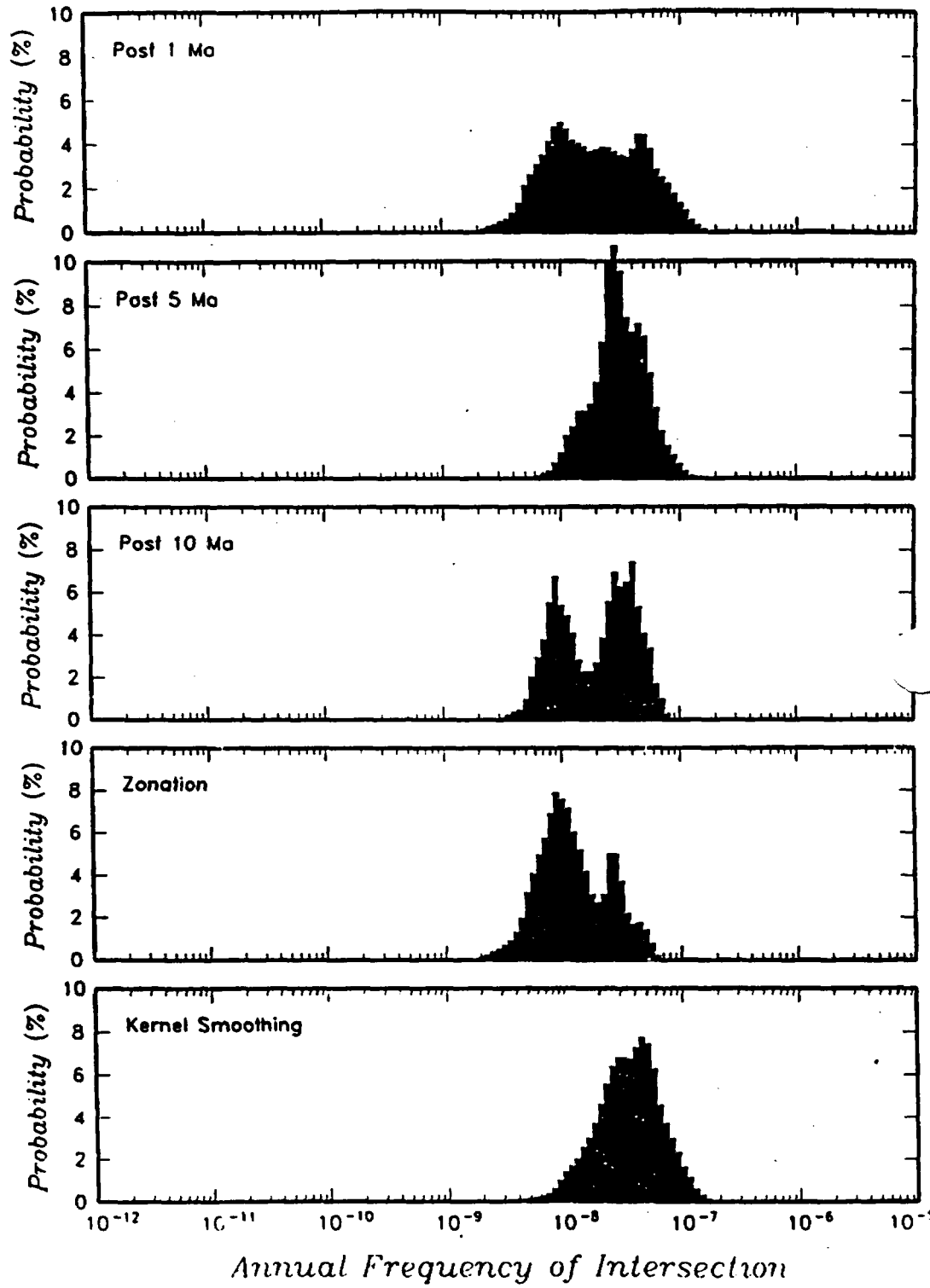


Figure 4-30 Effect of choice of and time period of interest and spatial model on computed hazard distrib for William Hackett's PVHA model.

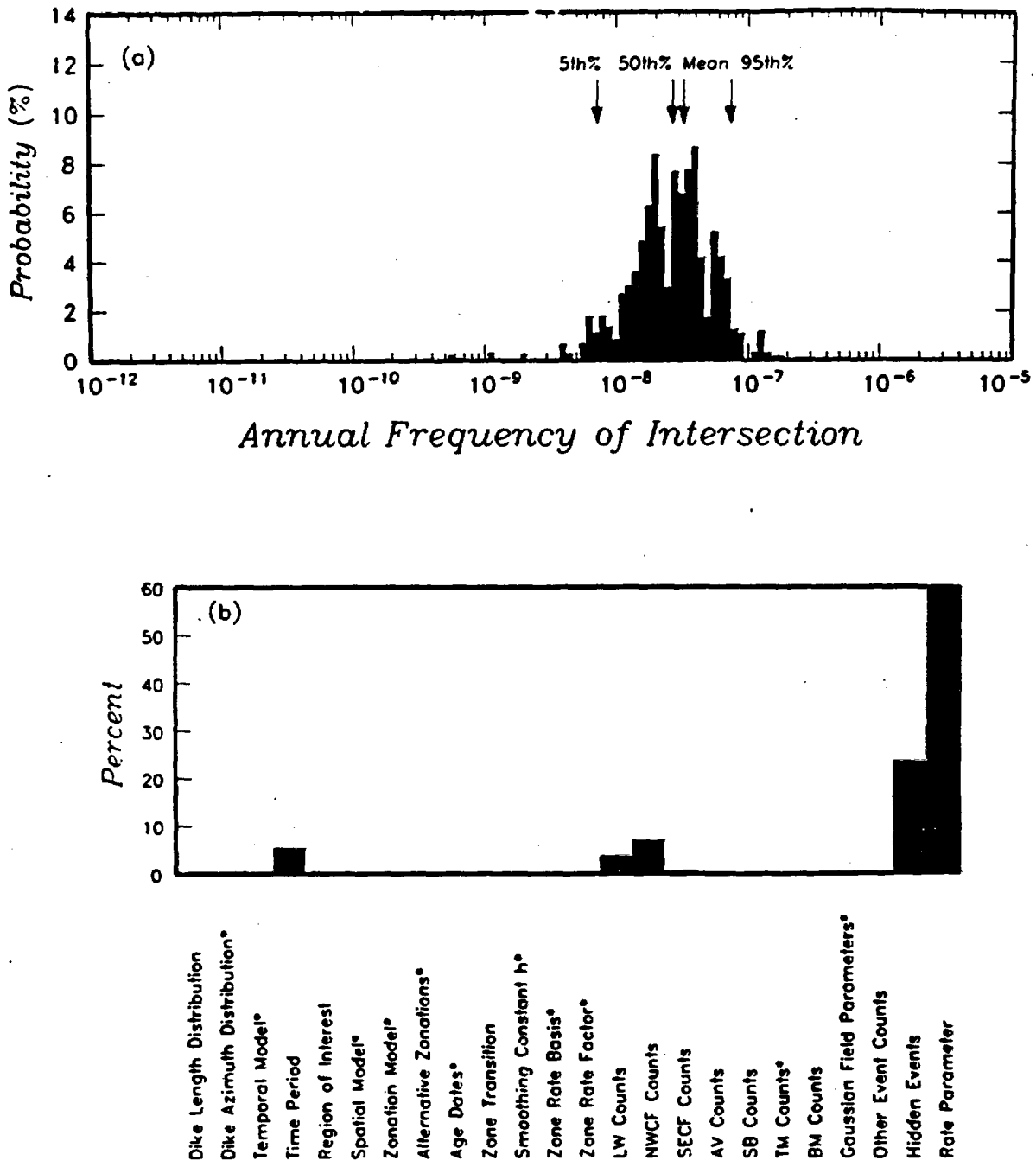


Figure 4-7 PVHA results obtained using George Thompson's PVHA model. (a) Distribution for annual frequency of exceedance (b) Relative contribution of uncertainty in various components of the PVHA model to the total variance in annual frequency of intersection. Components marked with a * were not treated as uncertain

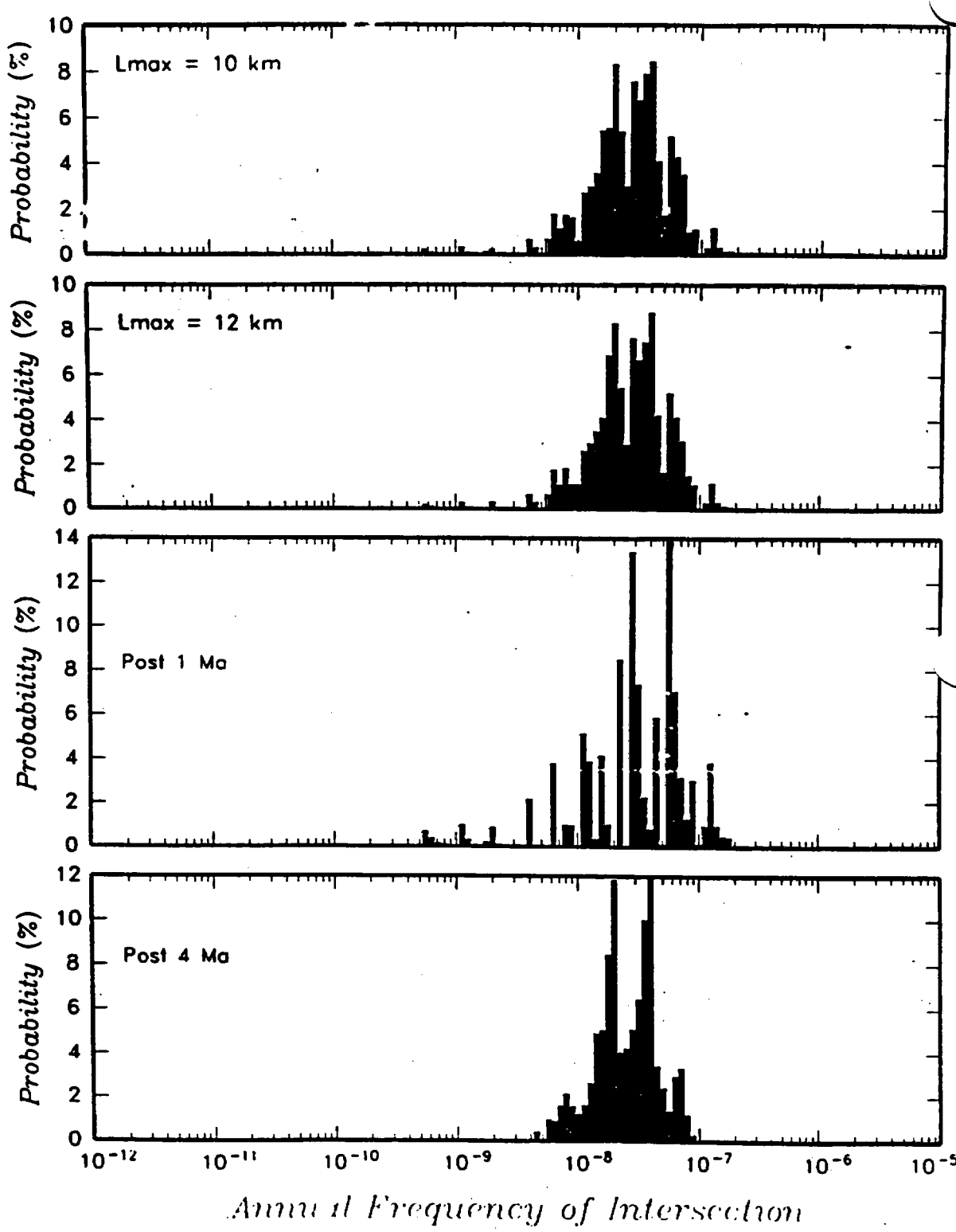


Figure 4-8 Effect of choice of maximum dike length and time period of interest on computed hazard distribution for George Thompson's PVHA model

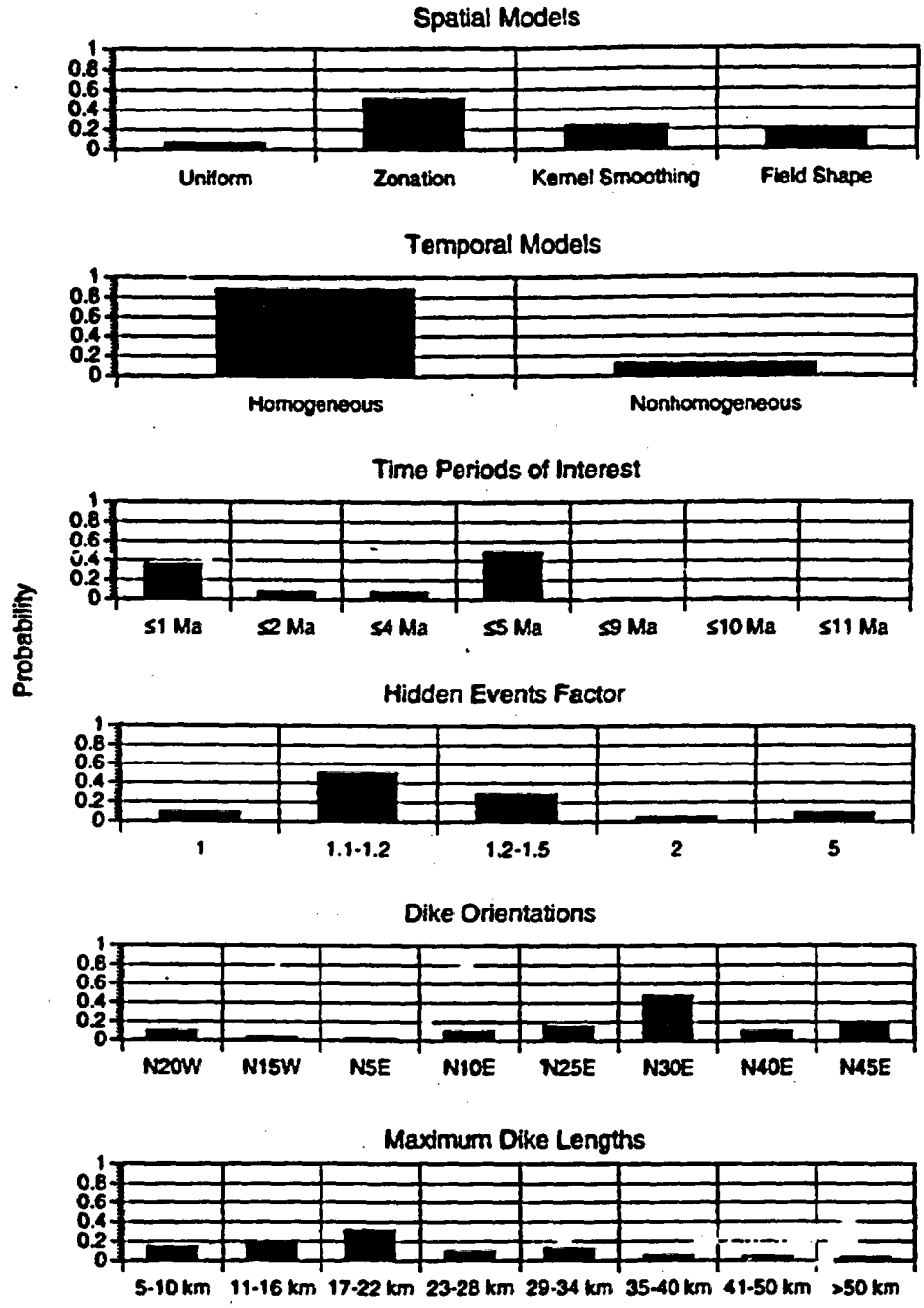


Figure 3-62 Summary of experts' assessments for components of the PVHA model.

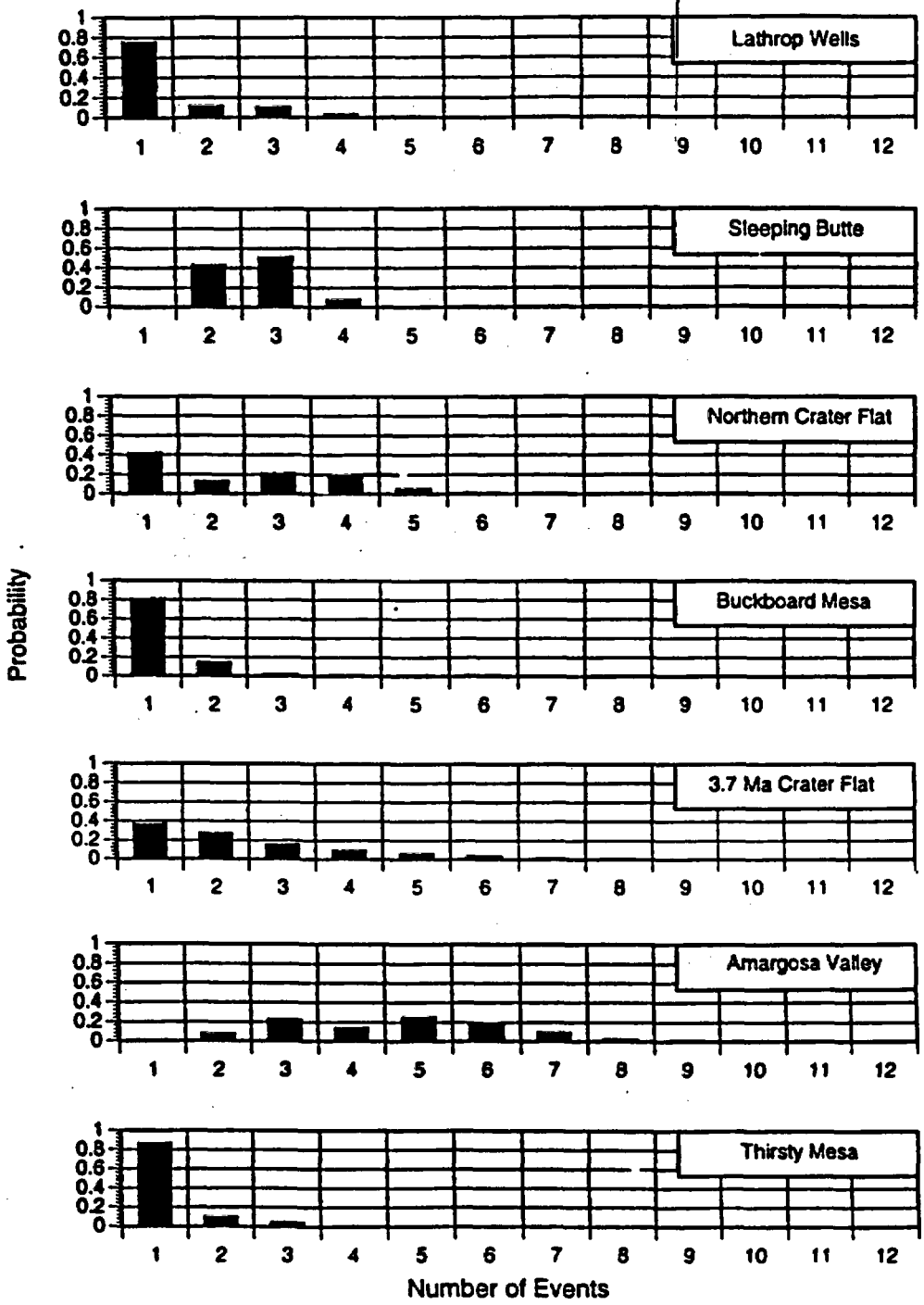


Figure 3-63 Summary of experts' assessments of the number of events at the various volcanic centers.

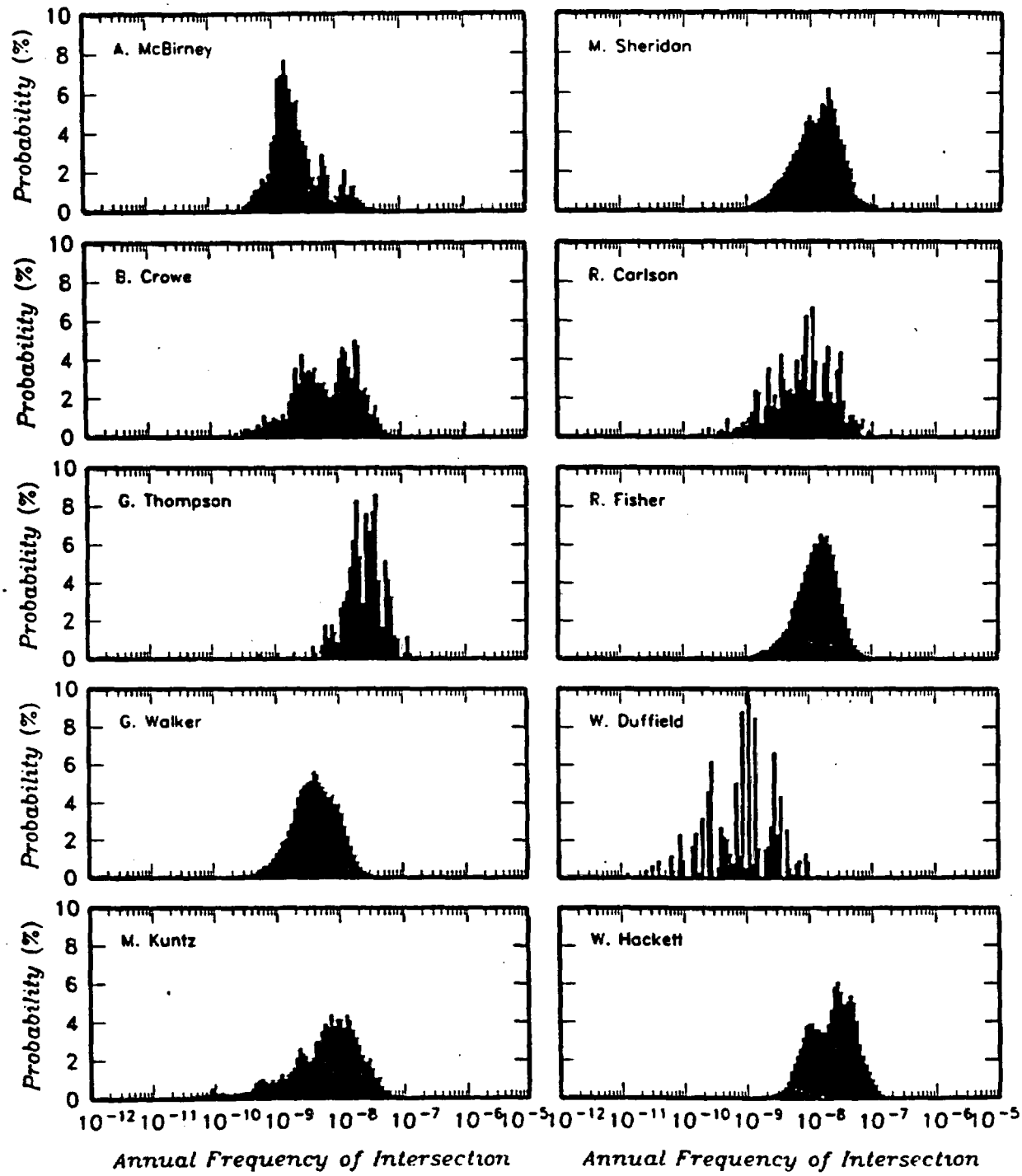


Figure 4-31 Comparison of individual expert distributions for frequency of intersection

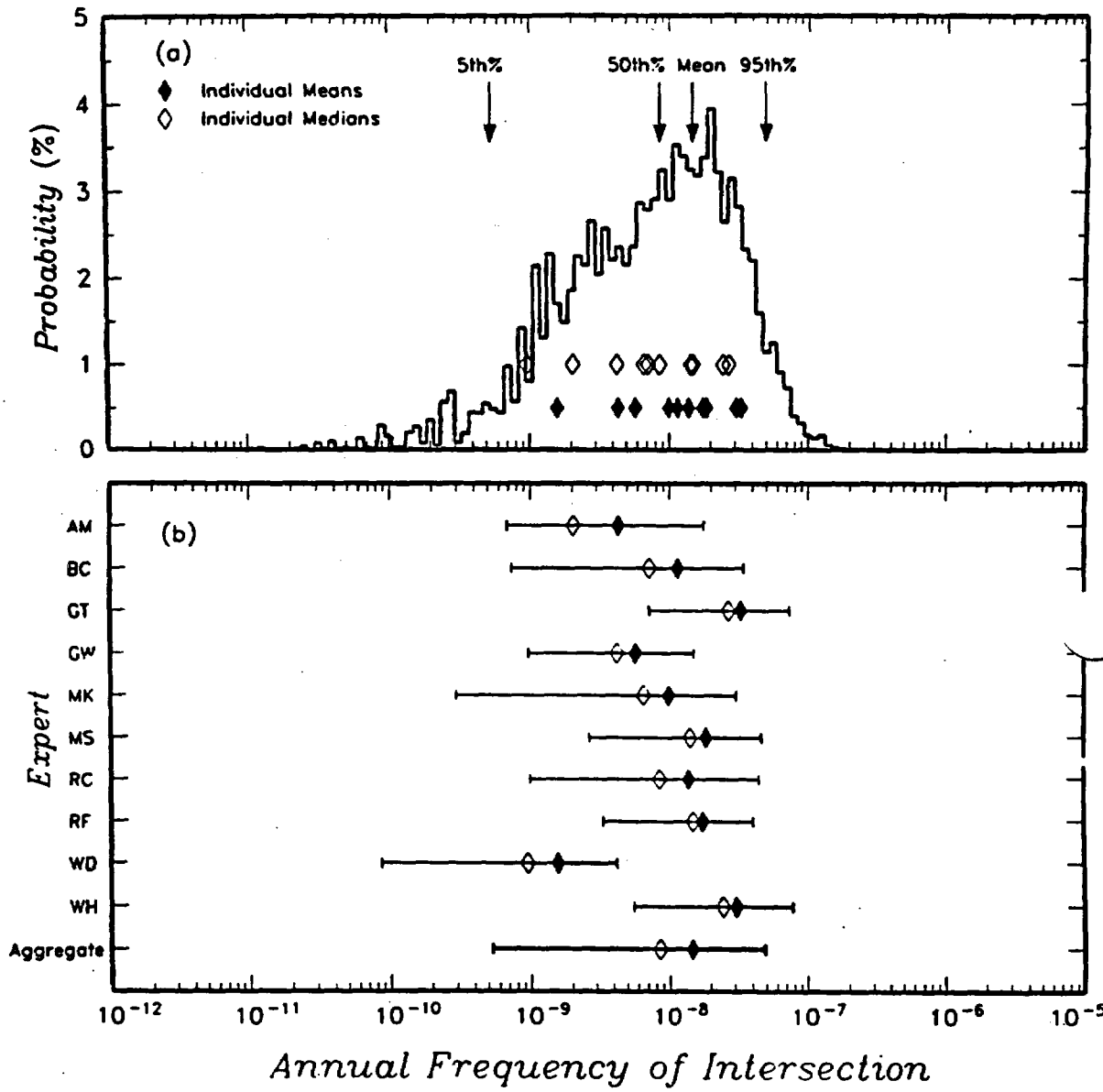


Figure 4-32 Aggregate results for frequency of intersecting the Yucca Mountain repository foot print by a volcanic event. (a) Aggregate distribution for frequency of intersection. (b) Individual and aggregate means, medians, and 90-percent confidence intervals (horizontal bars).

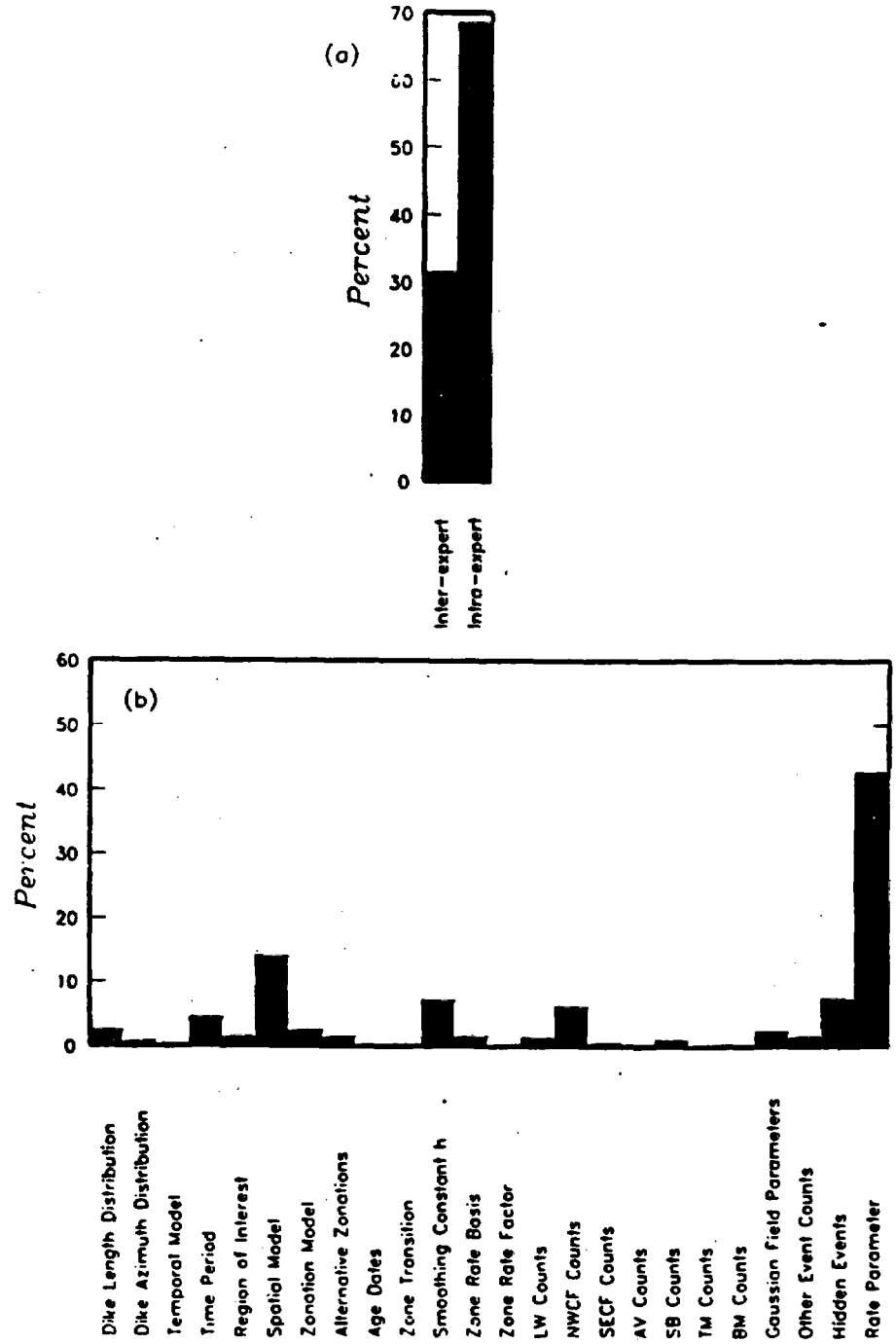


Figure 4-33 Relative contribution of uncertainty in various components of the aggregate PVHA model to the total variance in annual frequency of intersection. (a) Comparison of inter-expert and intra-expert components. (b) Breakdown of intra-expert component of variance

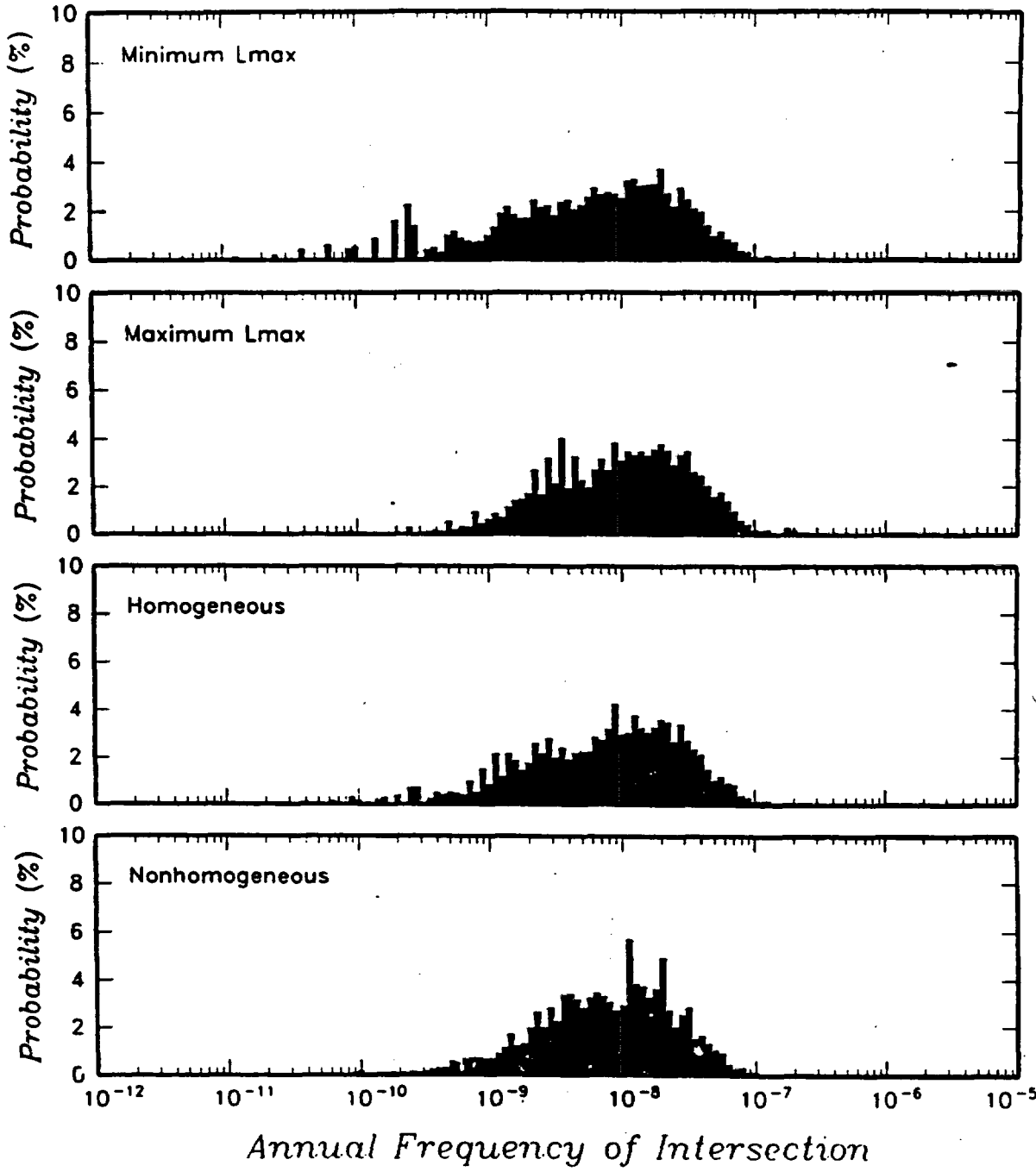


Figure 4-34 Effect of maximum dike length and temporal model on aggregate hazard distribution.

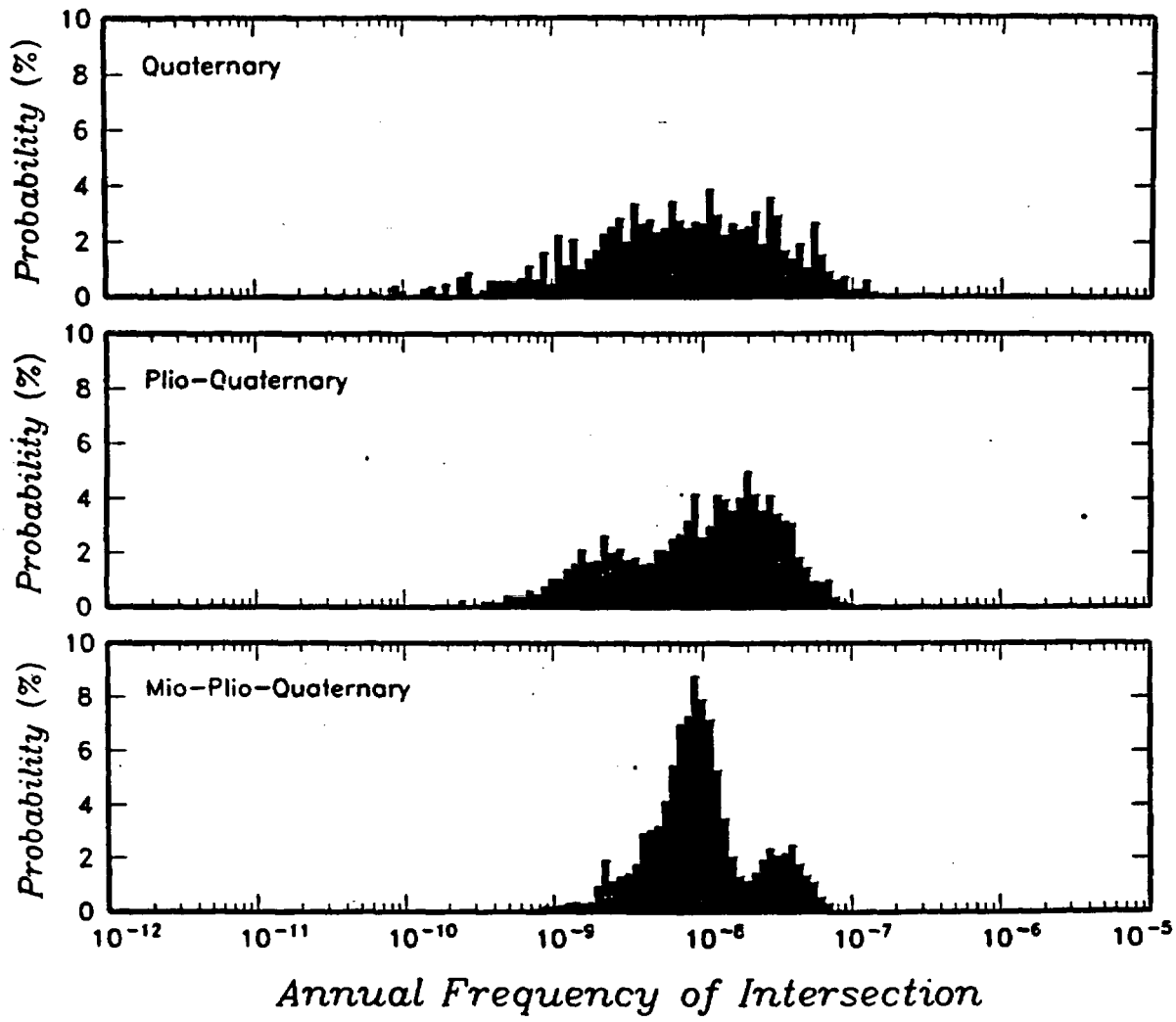


Figure 4-35 Effect of choice of time period on aggregate hazard distribution. Time periods are Quaternary (post 1 to 2 Ma), Plio-Quaternary (post ~5 Ma), and Mio-Plio-Quaternary (post ~10 Ma).

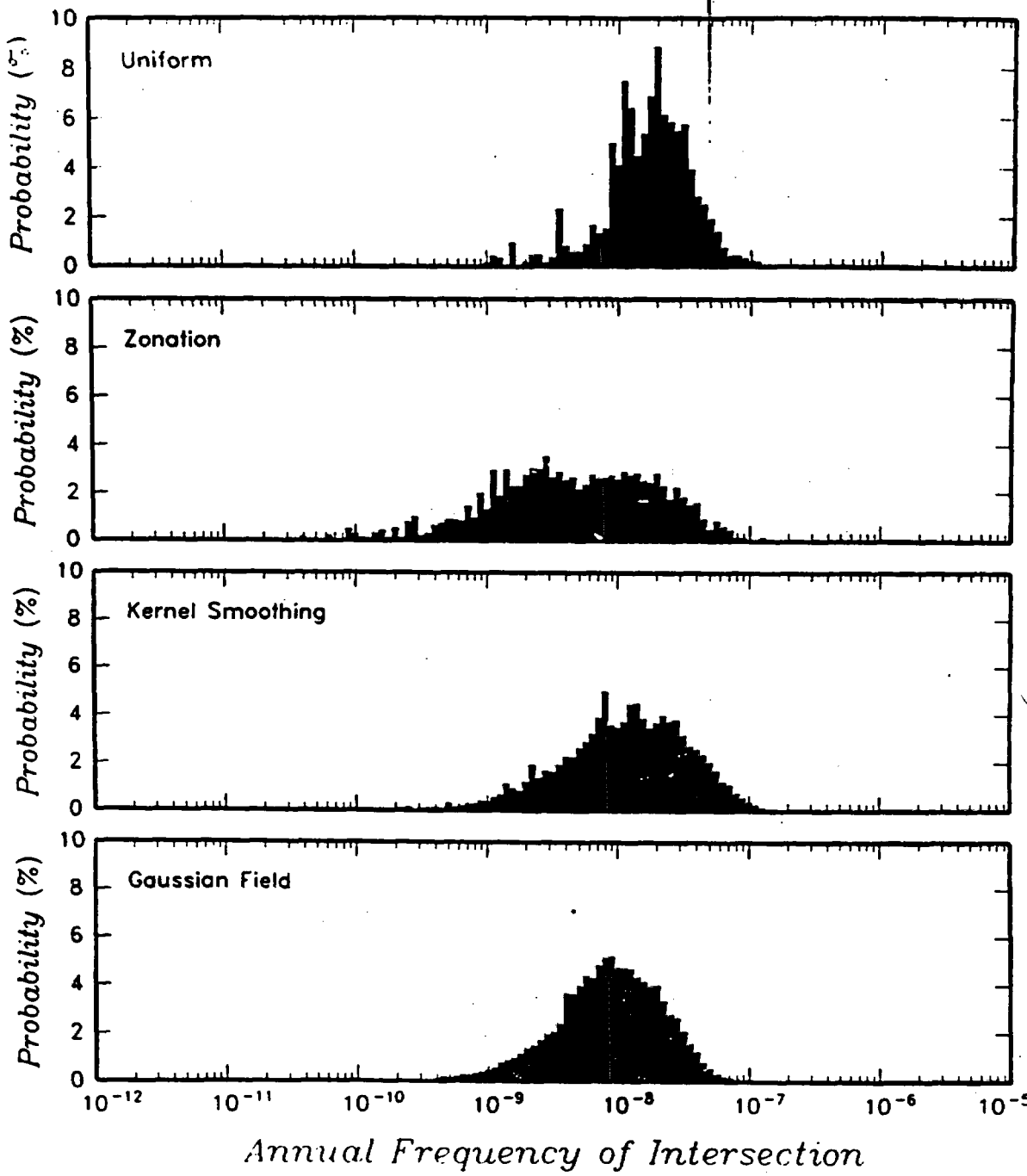


Figure 4-36 Effect of choice of spatial model on aggregate hazard distribution.

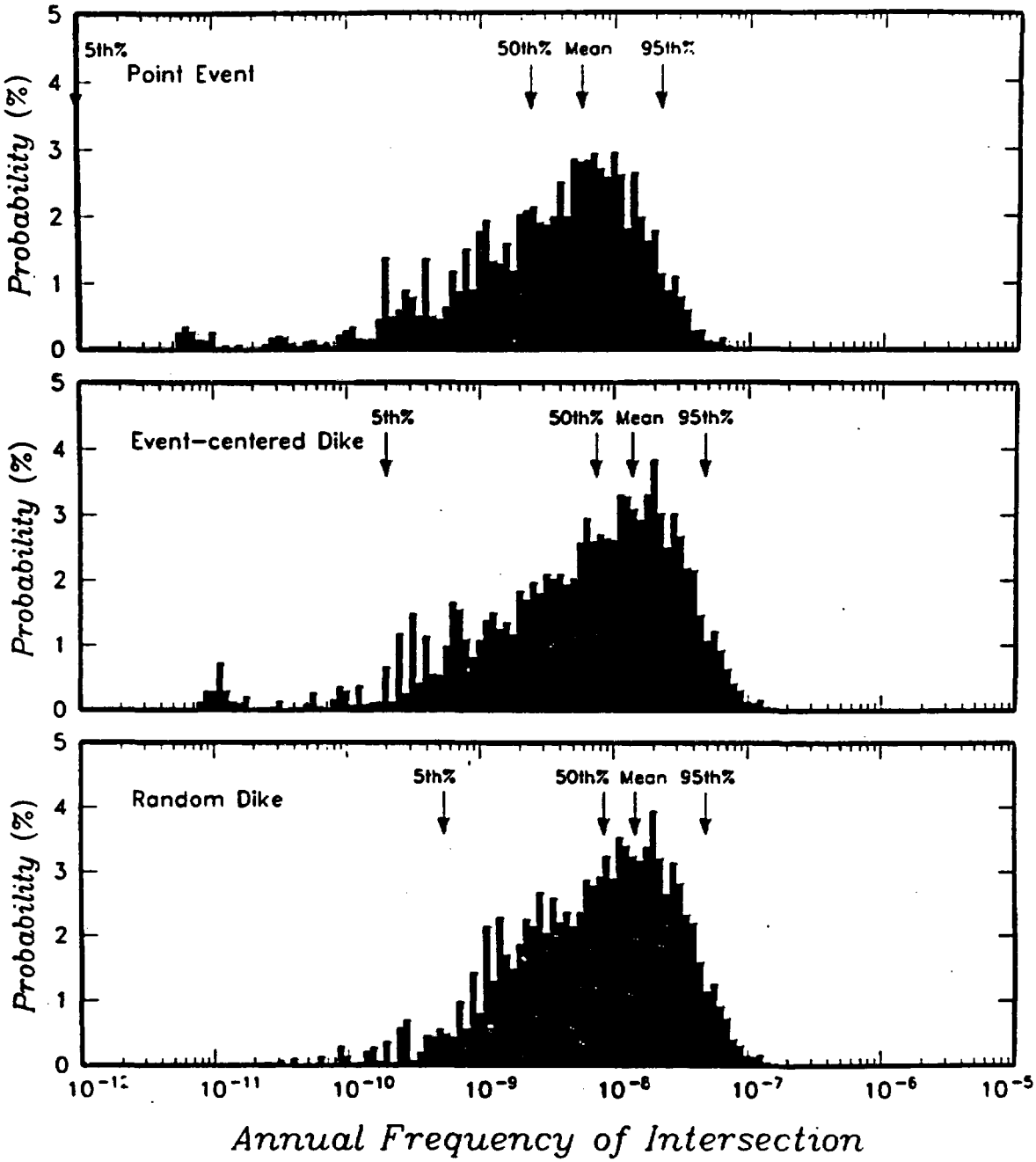


Figure 4-37 Comparison of aggregate distributions for frequency of intersection computed using the three event representations shown on Figure 3-11.

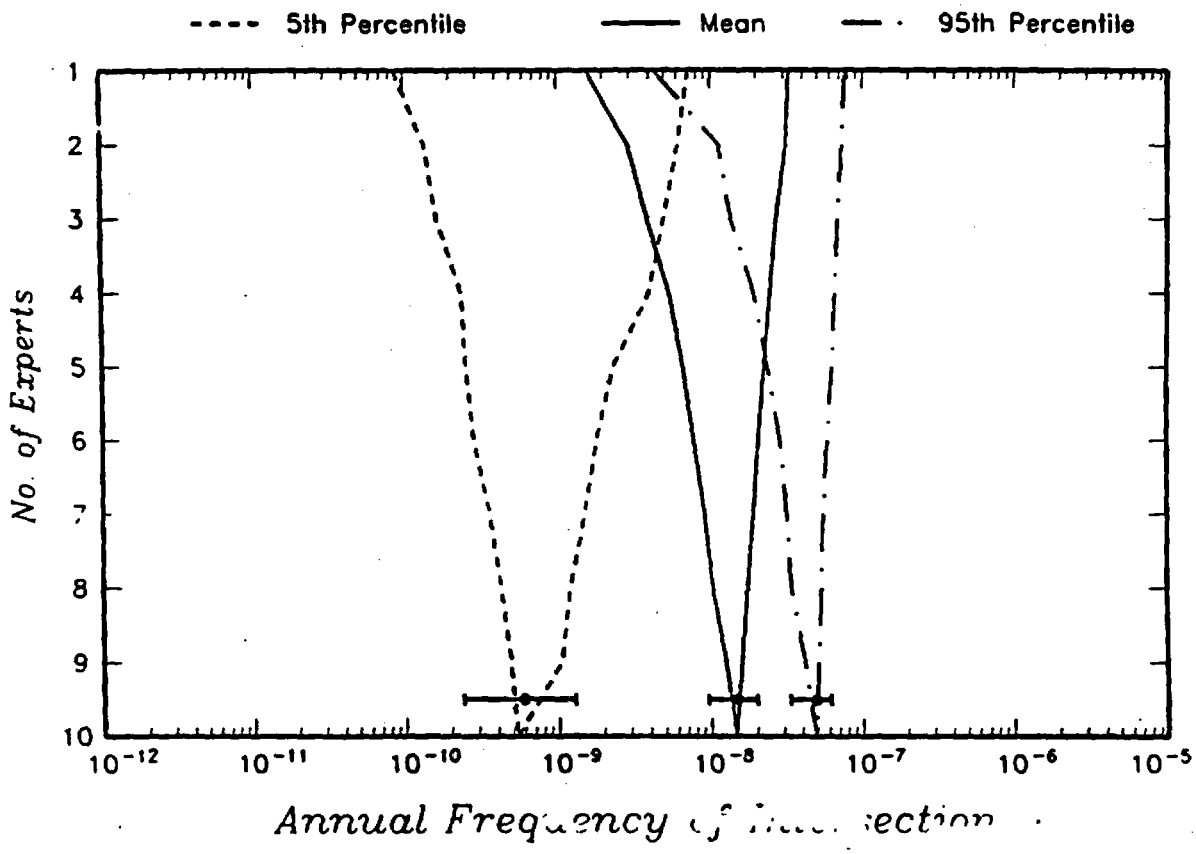


Figure 4-38 Evaluation of the variability in the estimates of the mean and 5th and 95th percentiles of the aggregate hazard distribution. The dashed, solid and dash-dot curves show the limits of the associated statistics considering all possible subsets of varying numbers of experts. The horizontal error bars show the 90-percent confidence intervals and the dots the median values for 1,000 bootstrap simulations of the aggregate distribution

PROBABILISTIC VOLCANIC HAZARD ANALYSIS (PVHA) FOR YUCCA MOUNTAIN, NEVADA

CONCLUSIONS

- The PVHA was conducted to evaluate probability of intersection of the repository by a volcanic event, including the uncertainty in the assessment
- Uncertainties were quantified using a panel of ten experts and incorporating alternative models and parameter values
- Consideration of available data, methods, analogues, and processes led to alternative spatial models, temporal models, and procedures for their calculation
- Annual frequency of intersection spans 1.5-2 orders of magnitude for each expert; 3 orders of magnitude for entire panel
- Rate parameter, choice of spatial model, smoothing constant, and counts in NW Crater Flat are significant contributors to uncertainty
- Mean frequency of intersection is 1×10^{-8}, with a 90 percent confidence interval of 5×10^{-10} to 5×10^{-8}

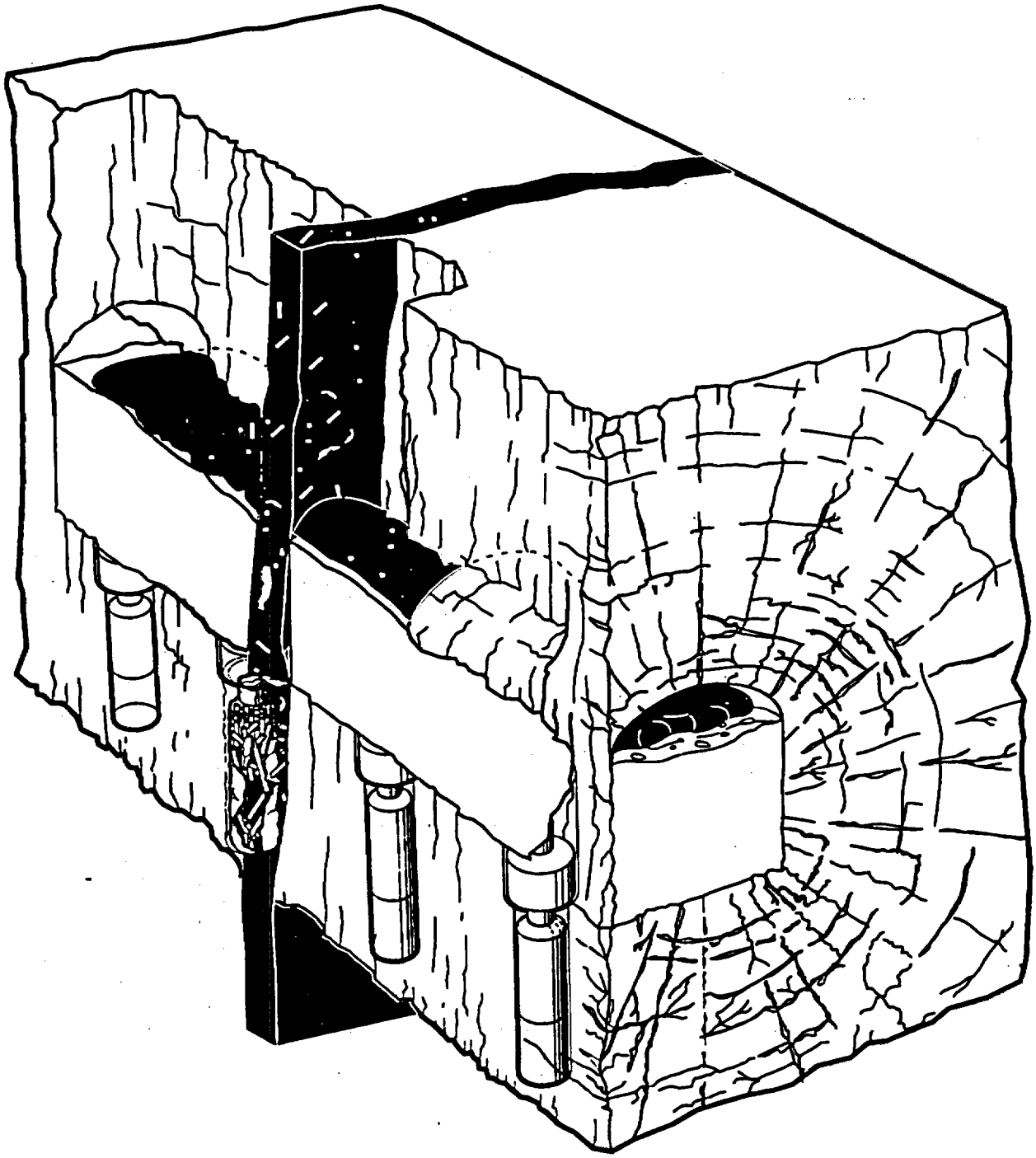
Overview

- Previous TSPA Analyses
  - TSPA-91
  - TSPA-93
- Recent Supporting Work
  - Probabilities
  - Consequences
- Preliminary Plans for TSPA-VA

History – TSPA-91

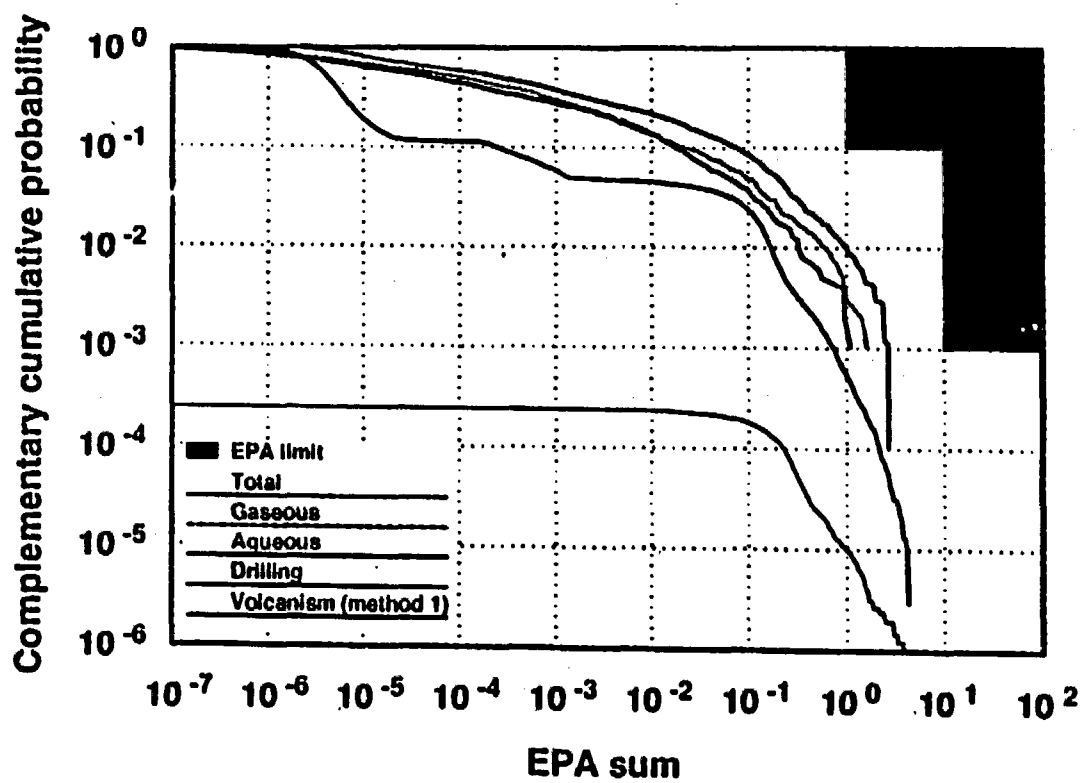
- Igneous intrusion into repository ruptures waste packages
  - SNF is entrained and carried to surface
- Radioactive waste contained in SCP containers (2.1 MTU/package)
- Amount of waste entrained is function of
  - volume of intrusive dike
  - extent of wall-rock erosion
  - area (height *x* length) of repository that dike passes through
- Random dike orientations, lengths, amounts of wall-rock erosion

Interaction of Dike with Repository



Summary of TSPA-91 Volcanism Results

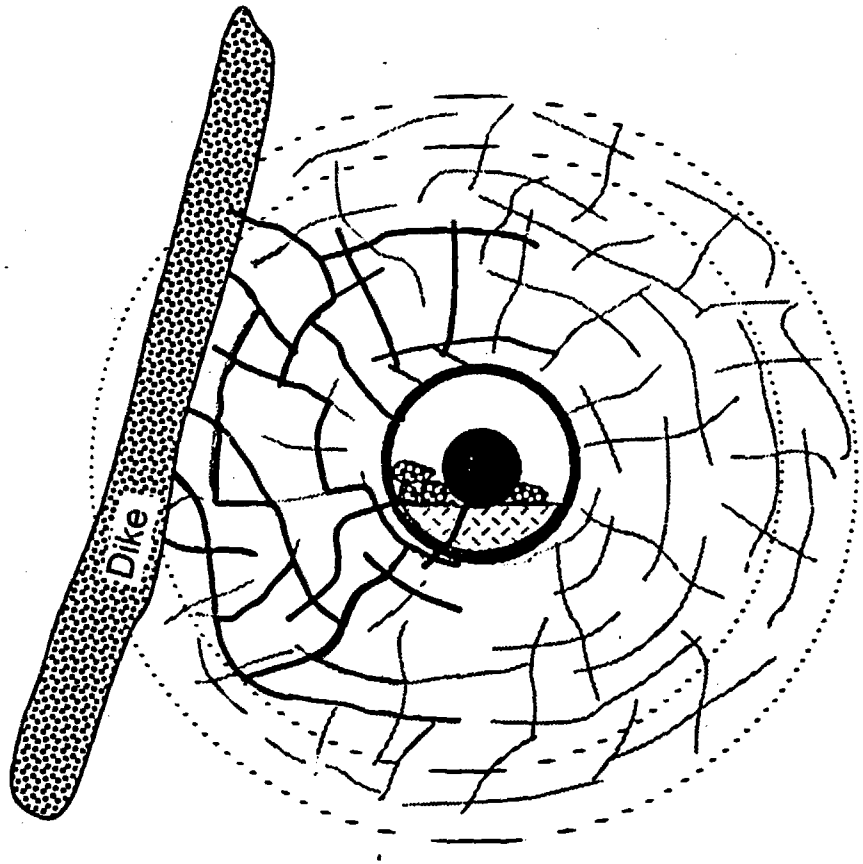
- Probability of occurrence of igneous event = 2.4×10^{-4} over 10,000 years
- Release models felt to be conservative
- Maximum release (expressed as old EPA sum) ≈ 1

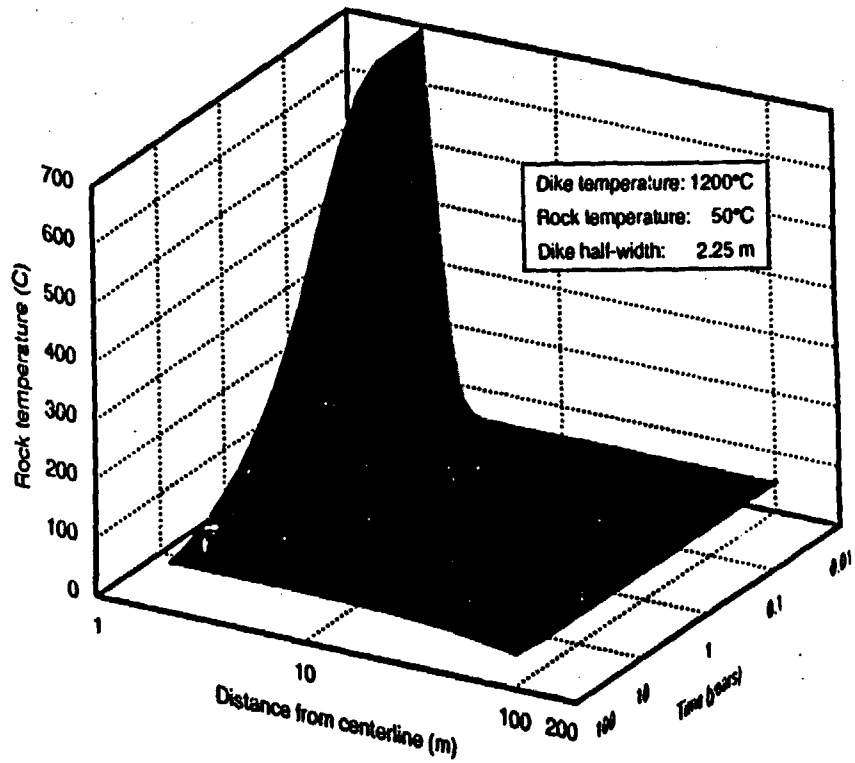


History – TSPA-93

- Igneous intrusion into repository accelerates waste-package and waste-form degradation
  - radionuclide source term for groundwater flow and transport is modified
- Both SCP and MPC (~8 MTU) waste packages used
- Waste package corrosion accelerated by:
  - heat
    - max. temperatures = 450–750°C
    - duration = 100–300 years
  - aggressive volatiles
    - sulfidation of carbon steel 10^4 greater at 500°C

Schematic of Magmatic Interaction

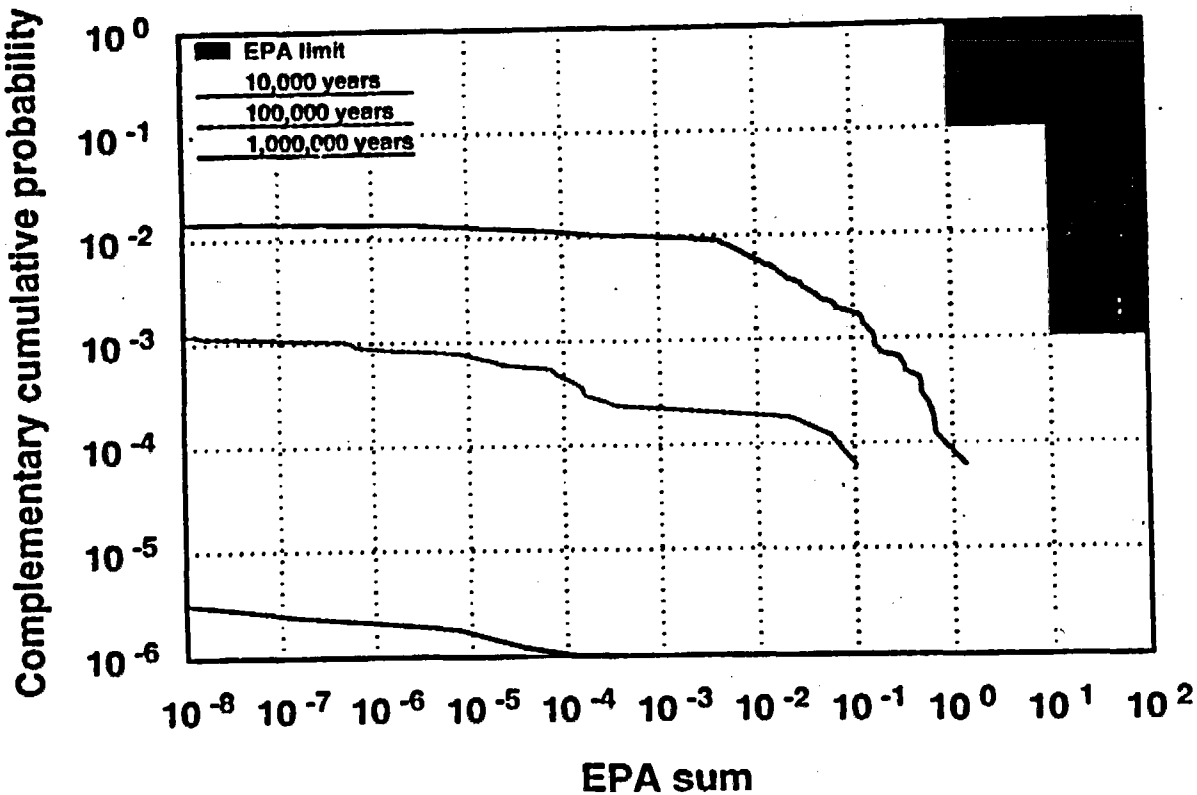




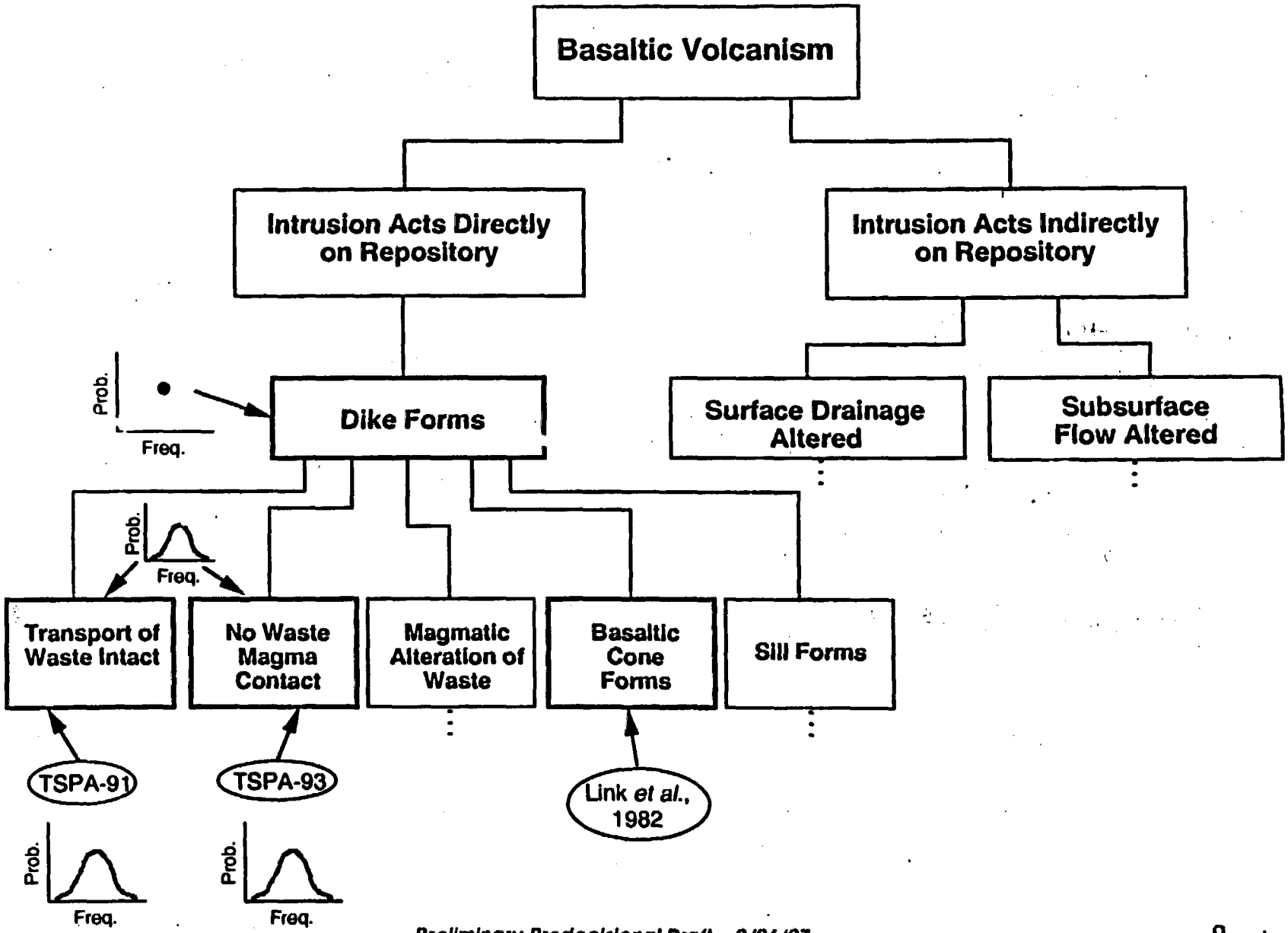
- Temperature of rock surrounding waste package increases
- Volatiles travel though fractures from dike to waste package

Summary of TSPA-93 Volcanism Results

- Both probabilities and consequences are low
  - $P[1|10^4 \text{ yrs}] = 2.4 \times 10^{-4}$
  - $P[1|10^6 \text{ yrs}] = 2.3 \times 10^{-2}$
- Maximum release at 10,000 years $\approx 10^{-4}$



Scenarios – Summary of Prior Work



Implications of Prior Work

- TSPA-91 analyses used very conservative models for waste entrainment
  - new analyses are unlikely to indicate greater consequences (releases or doses)
- TSPA-93 showed insignificant doses and releases from indirect effects of dike intrusion
  - new analyses must include indirect magma–waste interactions in addition to direct effects because they are pervasive
- Probability-of-occurrence estimates support assumption that direct effects from intrusion have low probability
  - probabilities of direct effects studied previously are conditional upon probabilities of dike intrusion
- Therefore, risk estimates for volcanism remain low

PA's Planned Use of Recent Supporting Work

- PVHA
  - provides credible estimates of probability of occurrence for intersection of dike with repository
    - pdf's permit better quantification of uncertainty in TSPA analyses
- LANL Volcanism Synthesis Report (Crowe and Valentine)
  - provides data on
    - erupted lithics
    - intrusion geometry
    - geochemical alteration around dikes and sills
    - vapor convection
- NRC/CNWRA
  - dispersion of tephra from basaltic eruptions

Examples of Modeling Improvements

- Surface releases
  - dike "plumbing"
    - extent of interaction of dike and repository drifts
    - depth of exsolution of gasses from magma
  - entrainment
    - density difference between magma and UO_2
- Indirect effects
  - lateral diversion of UZ flow and perched water
    - locally saturated flow
  - shortened path to WT
  - change in sorption

Preliminary Strategy for TSPA-VA

(Direct Interactions of Dike with Repository)

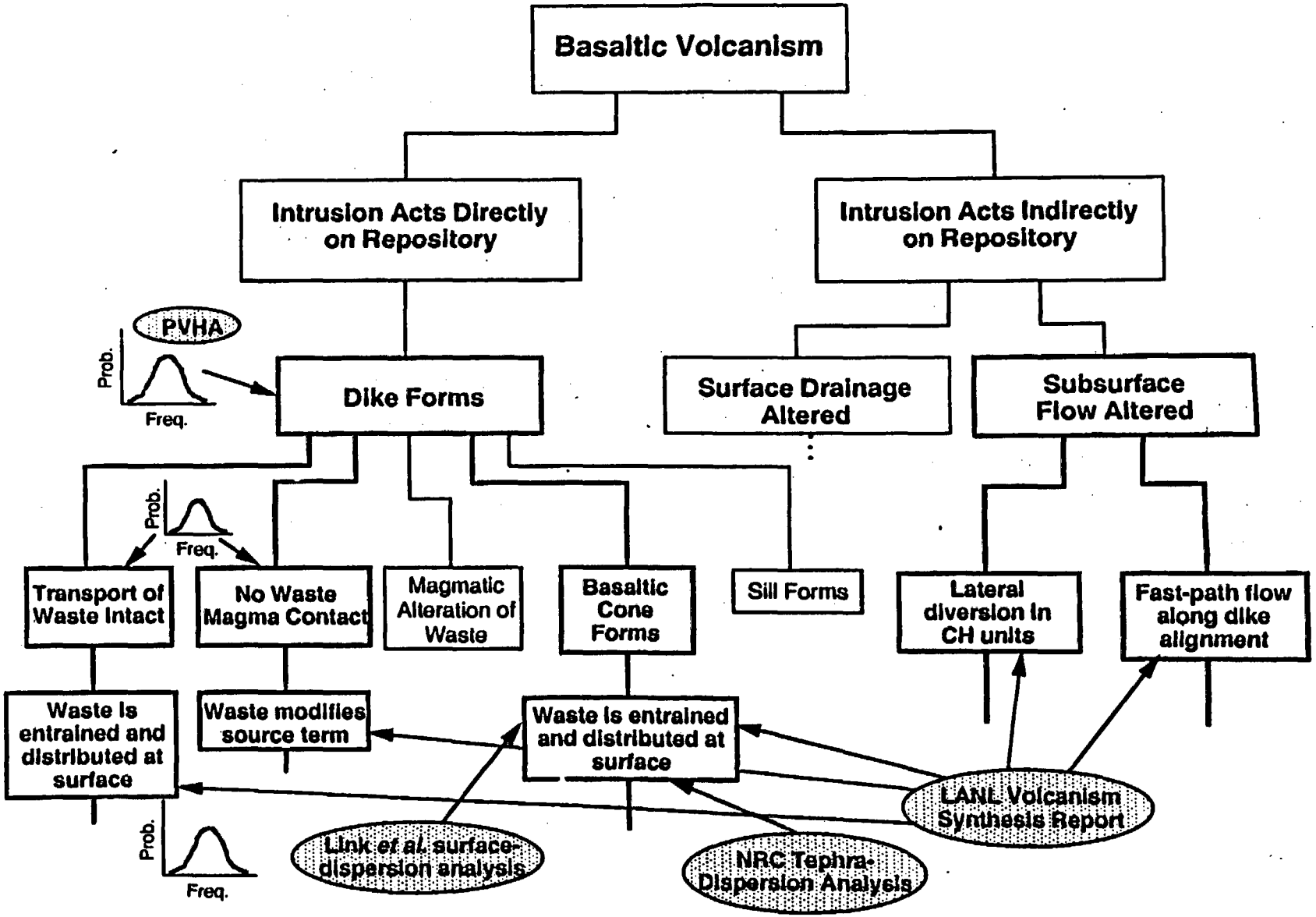
- Adapt new work for models of dissolution and entrainment of SNF in magma
  - erupted lithics and intrusion geometry for entrainment model
  - analyze consequences of tephra dispersion using NRC/CNWRA and Link *et al.* work
- Include indirect effects on waste packages
  - geochemical alteration and vapor movement to model waste-package degradation
- Apply probabilities of dike intrusion from PVHA to estimate risk from this scenario

Preliminary Strategy for TSPA-VA, Continued

(Analyze Indirect Consequences of Dike Intrusion)

- Introduce zone in 2-D or 3-D UZ and SZ models that represents the dike intrusion
  - relatively impermeable zone: dike as a flow barrier
  - relatively greater permeability zone: dike as a conduit
- Calculate flow fields, ponding, saturation, etc. as sensitivity study of dike permeability
- Water-table rise
  - investigated in TSPA-93 and TSPA-95: little effect on performance
  - possible re-analysis if a greater effect can be anticipated

Scenarios – Summary of Proposed Work



The Next Steps

(Preparation for TSPA-VA)

- Review process models to determine how they can be abstracted and incorporated into TSPA analyses
- Review open issues to see how well they are addressed by proposed analyses
  - list of issues from Igneous Activity Scenarios report (Barr *et al.*)
  - NRC concerns
    - coupled tectonic/seismic/volcanic events
    - impacts on SZ

Summary

- Disruptive events will be incorporated into TSPA-VA to the extent that
  - the consequences are expected to be detectable
  - the probabilities are not negligible
    - (inputs from PVHA)
  - the significance is perceived to be large
  - YMP resources permit inclusion

ATTACHMENT 4

United States
Nuclear Regulatory Commission

NRC INTRODUCTION

Presented: NRC/DOE Technical Exchange - volcanism
February 25-26, 1997

By:
John Trapp, Senior Geologist
Engineering and Geoscience Branch
Division of Waste Management
Office of Nuclear Material Safety and Safeguards
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STATEMENT OF ISSUE

NRC KEY TECHNICAL ISSUE

ESTIMATING OR BOUNDING THE CONSEQUENCE AND PROBABILITY OF IGNEOUS ACTIVITY AFFECTING THE REPOSITORY IN RELATIONSHIP TO THE OVERALL SYSTEM PERFORMANCE OBJECTIVE.

DOE WASTE CONTAINMENT AND ISOLATION STRATEGY - HYPOTHESIS FOR IGNEOUS ACTIVITY

VOLCANIC EVENTS WITHIN THE CONTROLLED AREA WILL BE RARE AND THE CONSEQUENCE OF THESE EVENTS WILL BE ACCEPTABLE.

agenda

AGREEMENTS SOUGHT

1. CONSIDERABLE NEW INFORMATION HAS BECOME AVAILABLE IN THE LAST YEAR WHICH SHOULD BE CONSIDERED IN EVALUATING THE PROBABILITY AND CONSEQUENCE OF IGNEOUS ACTIVITY.

2. THE BEST ESTIMATE OF DIRECT DISRUPTION OF THE REPOSITORY BY BASALTIC VOLCANO ACTIVITY IS BETWEEN $10E^{-7}$ AND $10E^{-8}$ PER YEAR.

AGREEMENTS SOUGHT (CONT)

3. WHILE BASALTIC VOLCANISM IS A LOW PROBABILITY EVENT, THE PROBABILITY IS HIGH ENOUGH THAT ESTIMATES OF THE CONSEQUENCE OF SUCH ACTIVITY WILL BE NEEDED IN ANY EVALUATION OF THE PERFORMANCE OF THE REPOSITORY DURING THE POSTCLOSURE PERIOD.

4. FURTHER WORK IS NEEDED BY DOE AND NRC IN THE AREA OF CONSEQUENCE FOR TSPA-VA.

5. BASED ON CURRENT INFORMATION, SILICIC VOLCANISM NEED NOT BE EVALUATED IN THE PERFORMANCE OF A REPOSITORY DURING THE POSTCLOSURE PERIOD.

ATTACHMENT 5

GEOLOGICAL SETTING

NRC DWM Program Element Manager - John Trapp

CNWRA Element Manager - H.L. McKague

PRESENTED BY

CHUCK CONNOR

February 25, 1997

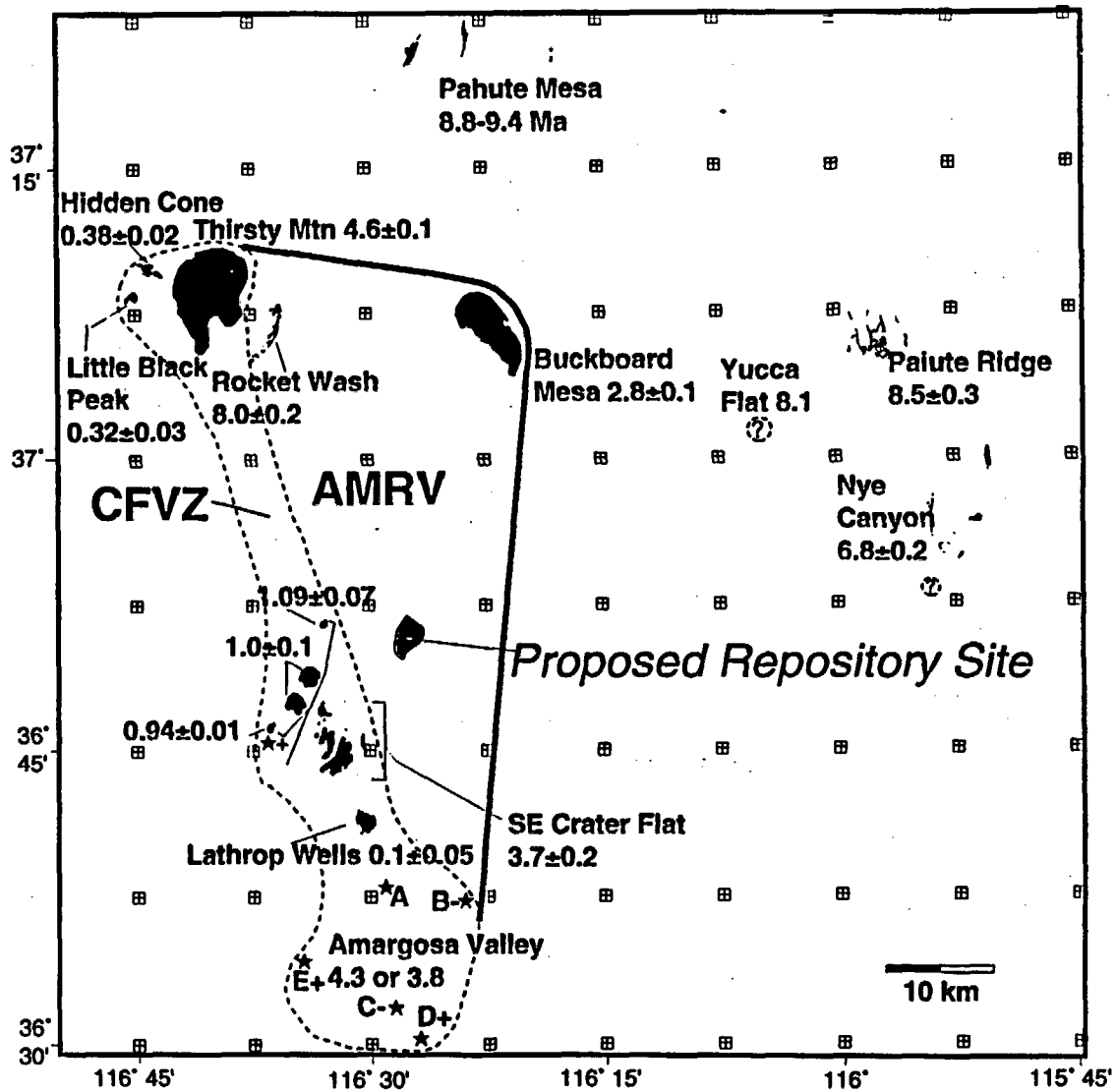
CNWRA Contributors

C. Connor, M. Conway, D.Ferrill, S. Greenon, B. Henderson, B. Hill, M. Jarzemba, P. La Femina, S. Magsino, L. McKague, R. Martin, J. Stamatakos

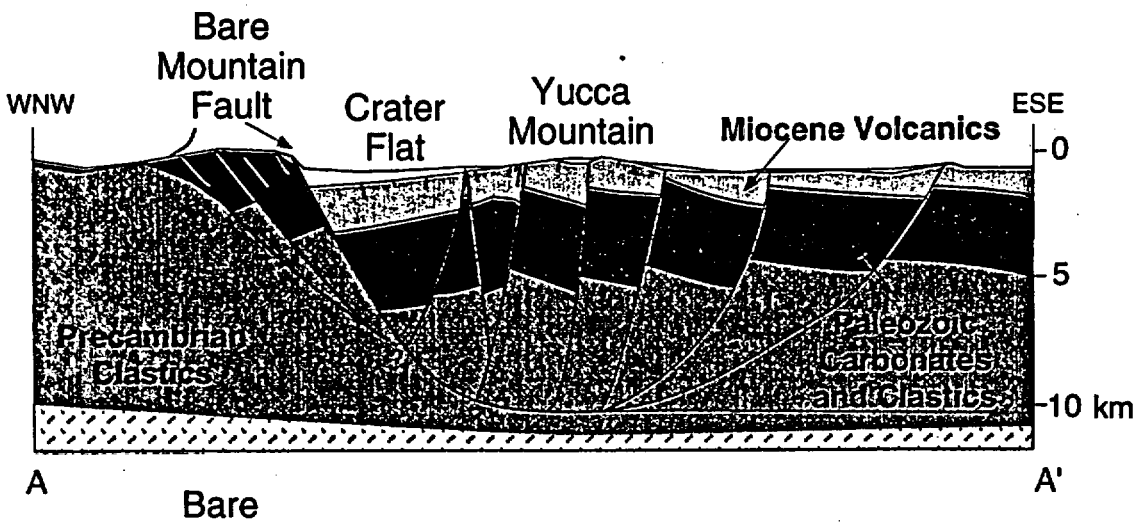
OUTLINE

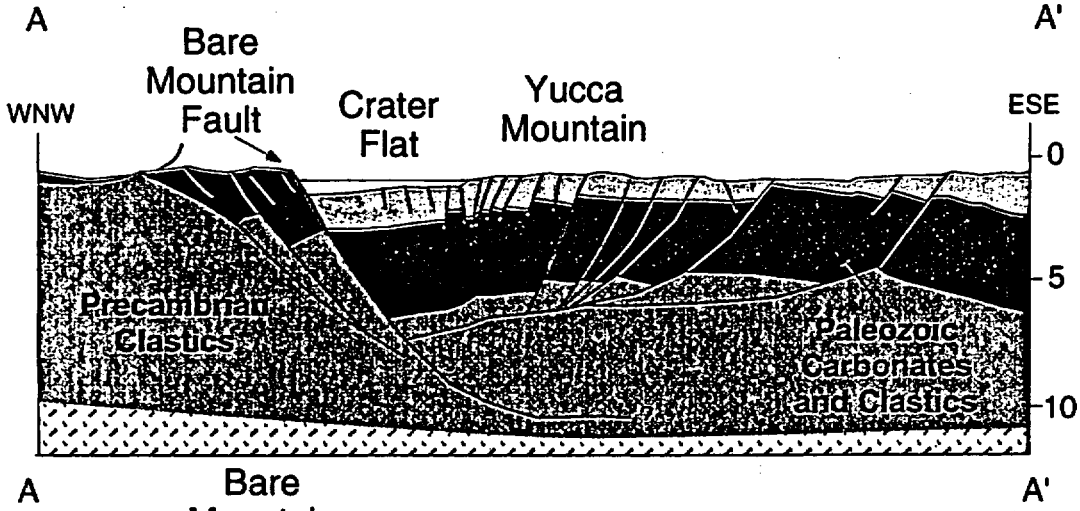
- Regional Structural Setting Of Basaltic Volcanoes Near Yucca Mountain
- Recent Geophysical Surveys And Their Significance
- Summary of Geologic Factors to be Included in Probability Models

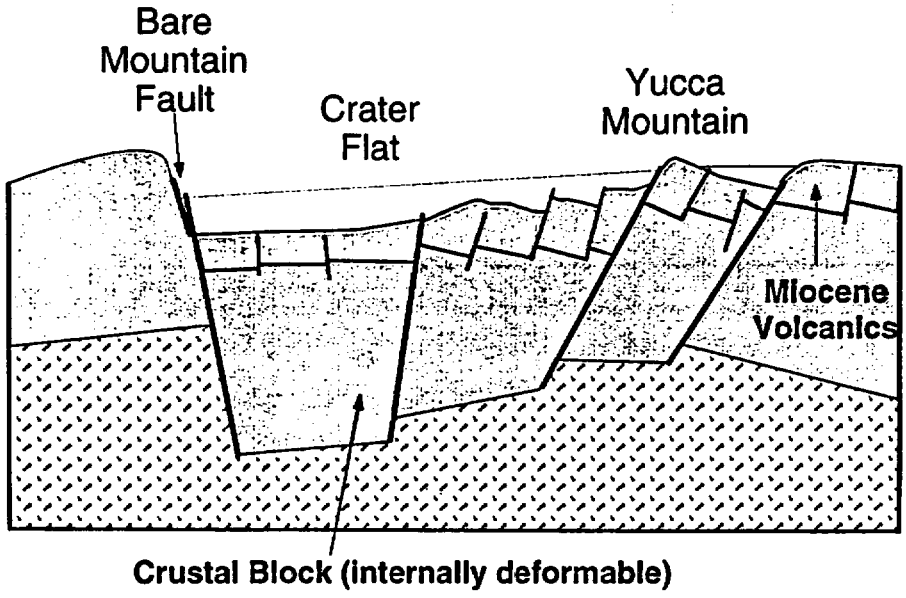
VENT LOCATIONS AND SOME STRUCTURAL ZONES



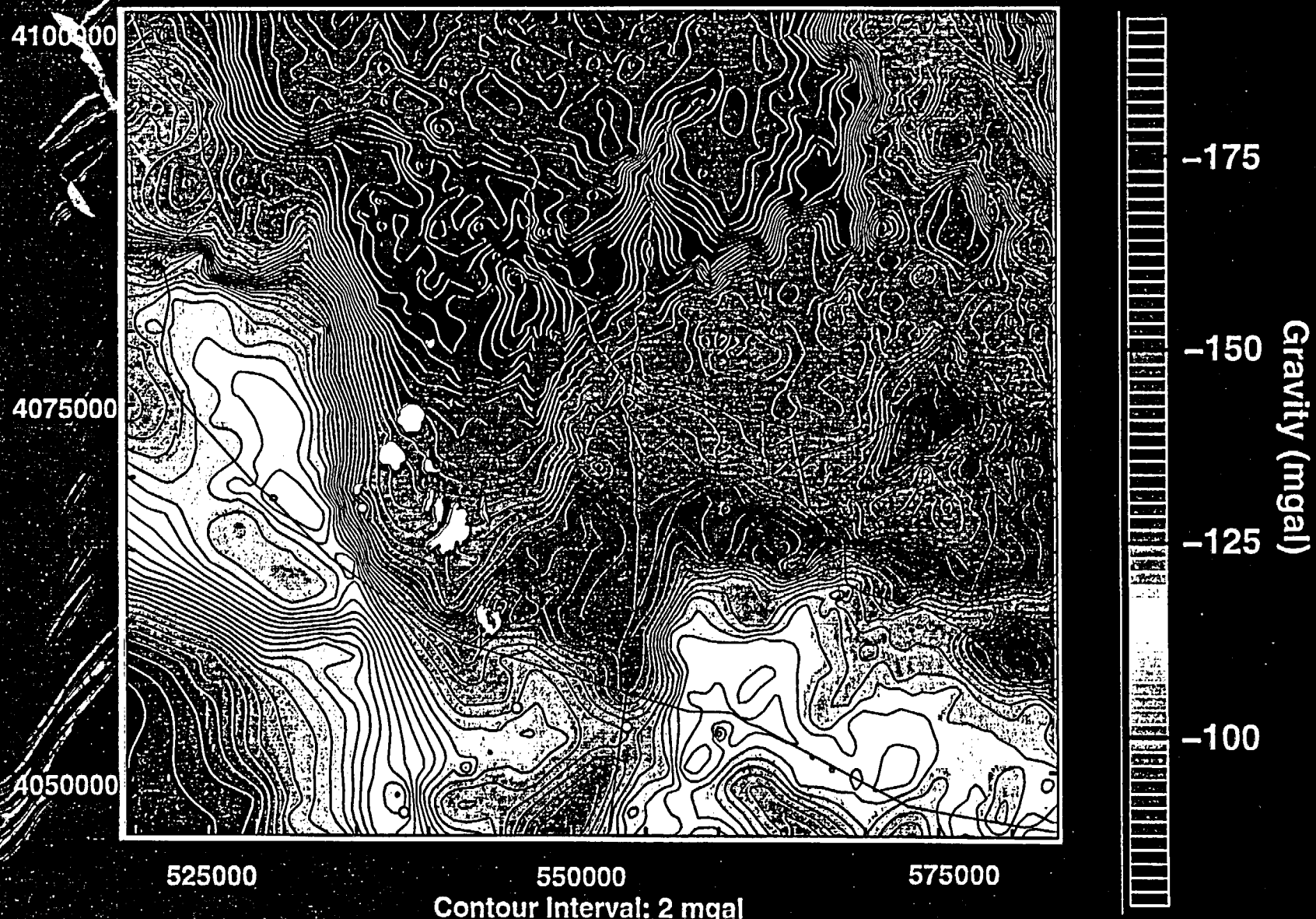
Cross-Sections Through Crater Flat and Yucca Mountain



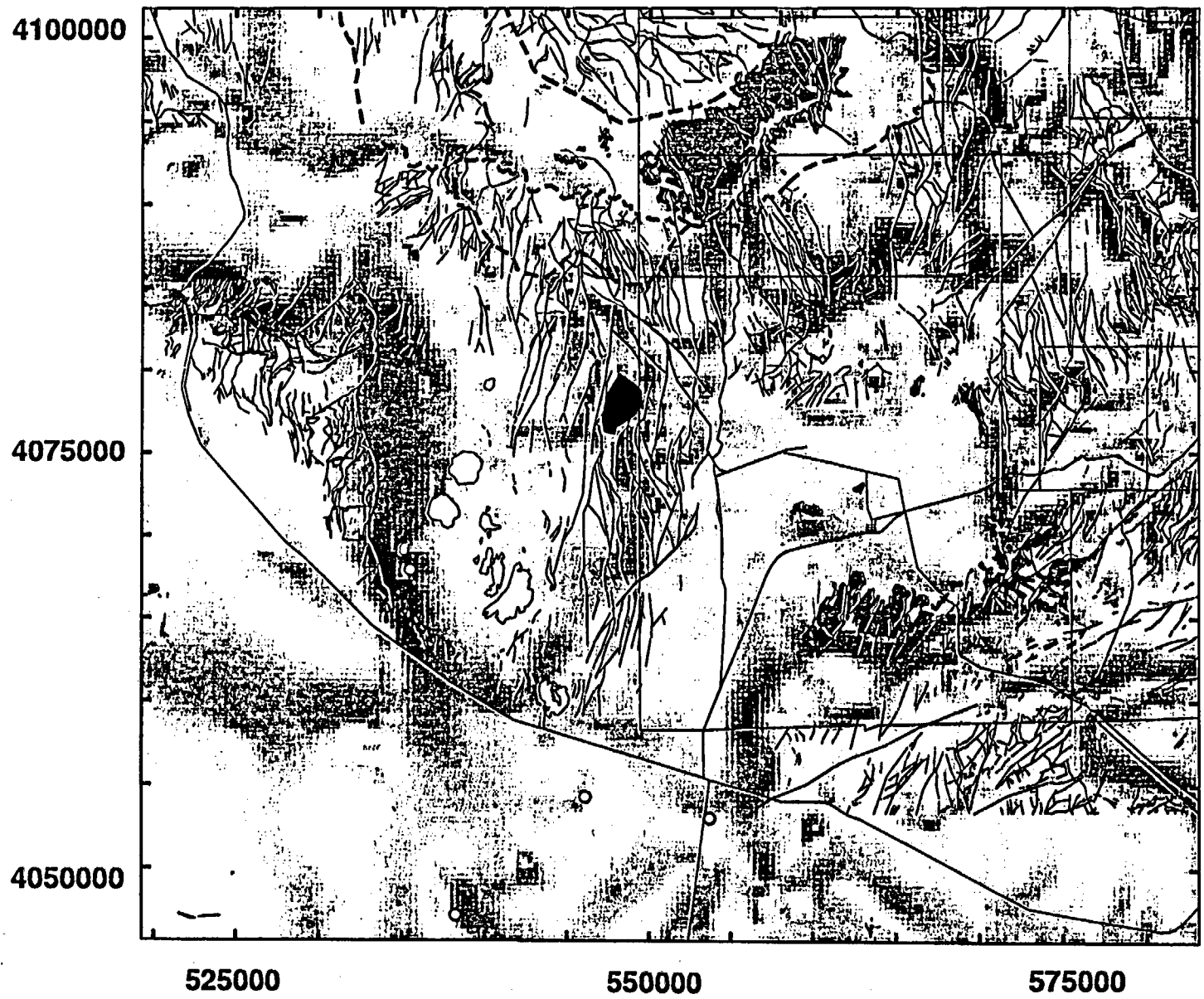




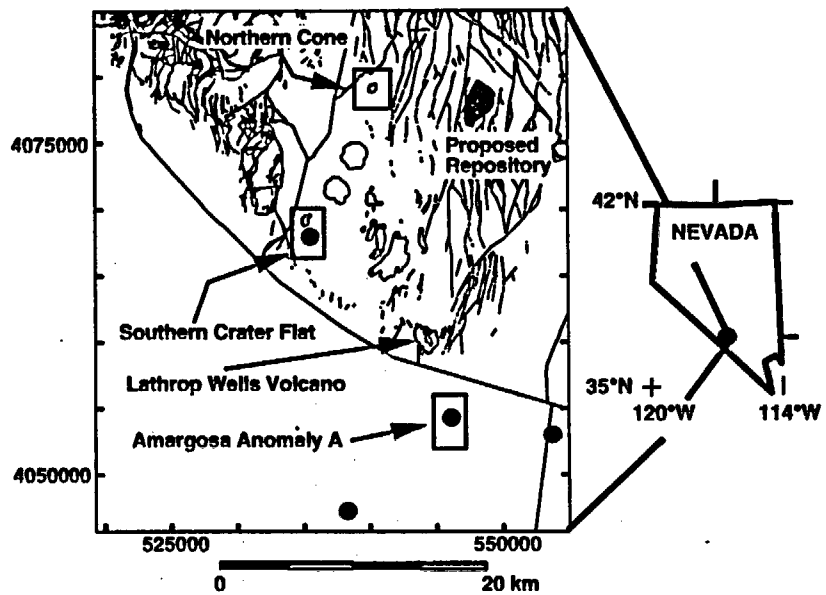
Comparison of Gravity Anomalies and Volcano Locations in the Yucca Mountain Area



Comparison of Horizontal Gravity Gradient and Volcano Locations in the Yucca Mountain Area



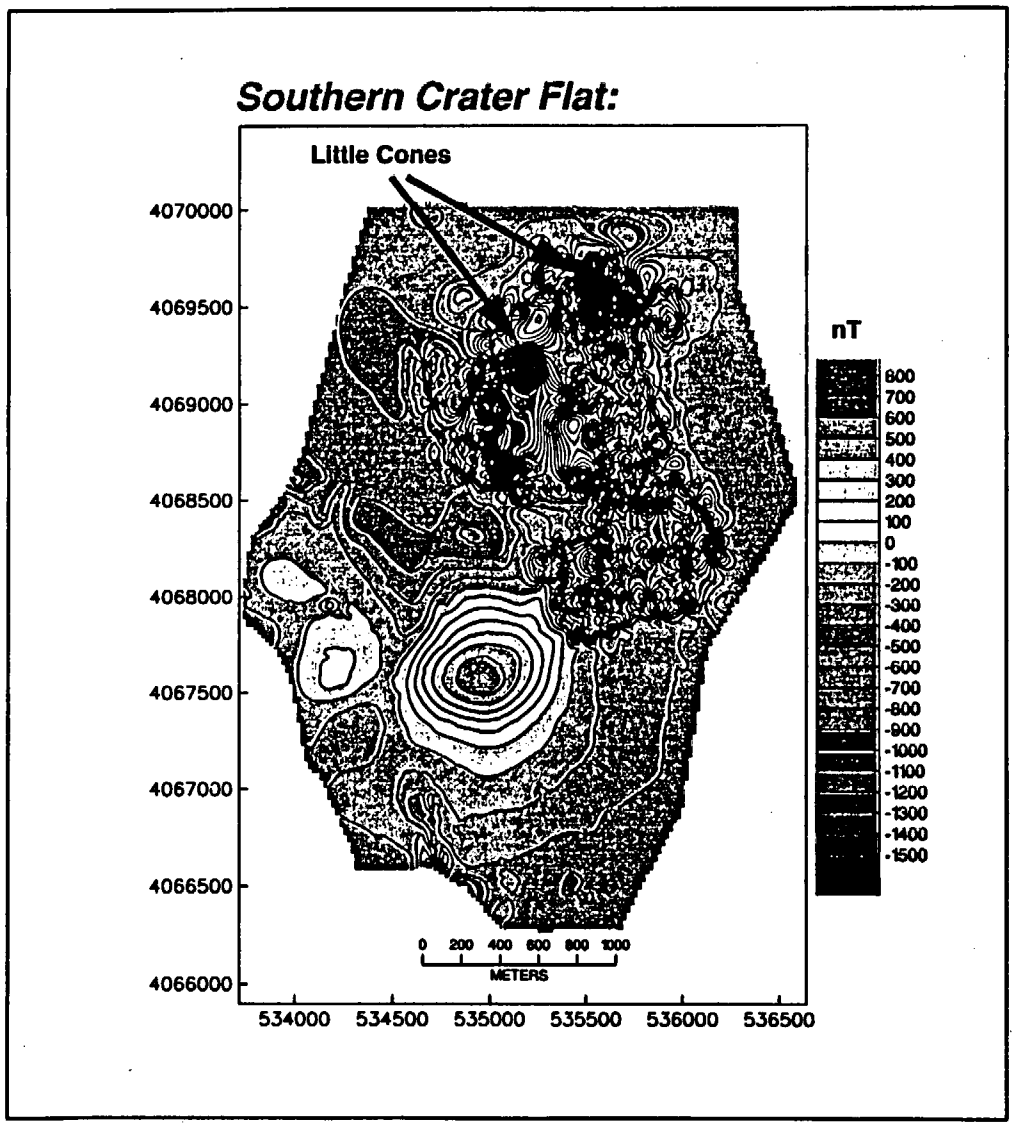
CNWRA Ground Magnetic Surveys



Three CNWRA ground magnetic surveys:

- Southern Crater Flat
- Amargosa Anomaly A
- Northern Cone

CNWRA Ground Magnetic Surveys



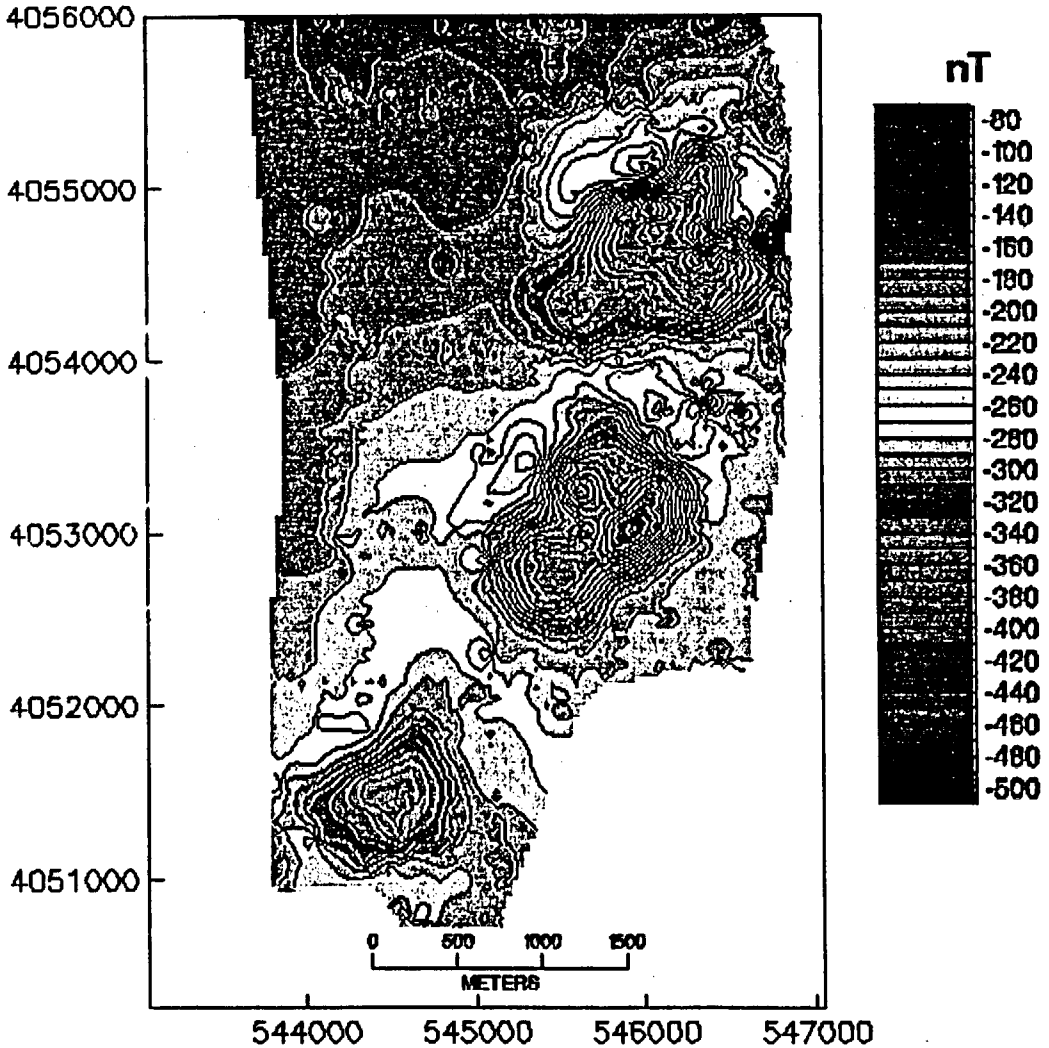
Three magnetic anomalies identified and mapped in southern Crater Flat

Little Cones comparable in volume to Red and Balck Cones

Possible buried volcano at 150 to 200 m

Dike trending parallel to Bare Mountain Fault

CNWRA Ground Magnetic Surveys



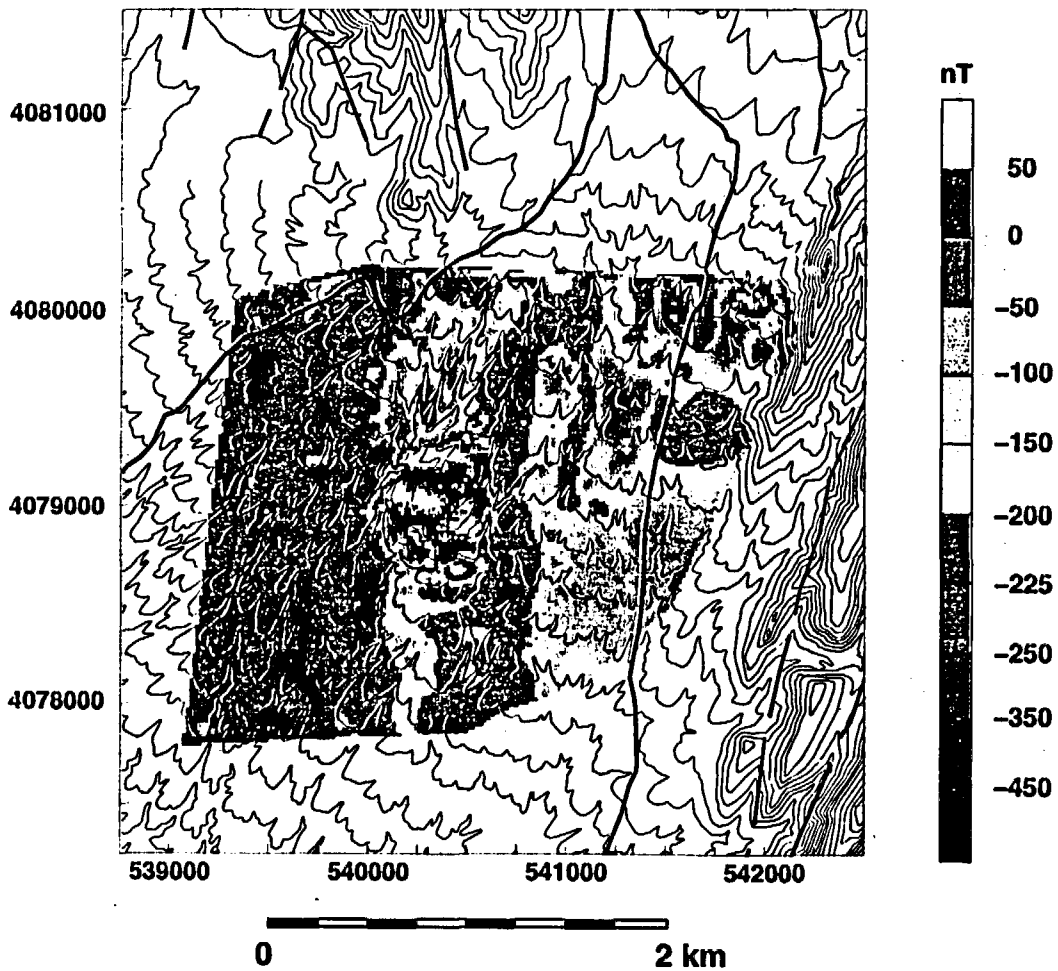
Ground Magnetic Survey of Amargosa Anomaly A

Reveals three distinct reversely polarized anomalies

Interpreted as buried basaltic volcano edifices

Further evidence of the importance of NE trending alignments

CNWRA Ground Magnetic Surveys



Northern Cone Survey illustrates the relationship between basaltic volcanoes and faults

SUMMARY OF GEOLOGIC SETTING OF VOLCANISM

PROBABILITY MODELS OF VOLCANISM SHOULD ACCOUNT FOR THE FOLLOWING FEATURES:

- **CLUSTERED VOLCANISM IN CRATER FLAT**
- **ASSOCIATION OF VOLCANOES AND FAULTS**
- **PREVALENCE OF NE-TRENDING VENT ALIGNMENTS**
- **LOW AND PERSISTENT RECURRENCE RATE**

ATTACHMENT 6

CNWRA INVESTIGATIONS OF YMR GEOLOGIC SETTING RELEVANT TO IGNEOUS ACTIVITY

FIN D1035
NRC DWM Program Element Manager: J.S. Trapp
CNWRA Element Manager: H.L. McKague

Presented at the February 25-26,1997
Technical Exchange on Igneous Activity

by

Dr. Brittain Hill
Research Scientist

CNWRA Contributors
C. Connor, M. Conway, D. Ferrill, S. Greenan, B. Henderson, B. Hill,
P. LaFemina, S. Magsino, L. McKague, R. Martin, J. Stamatakos

EXTENT OF YMR VOLCANIC SYSTEM

- Need a geologic basis for system definition: spatial, temporal, structural, isotopic
- Funeral Fm. basalts = steady-state recurrence <6 Ma

SILICIC PUMICE IN CRATER FLAT

- Unusually abundant, coarse-grained reworked rhyolitic pumice in SE Crater Flat has reported date of 6.3±0.8 Ma. If correct, would represent a significant post-caldera (i.e., <9–11.5 Ma) silicic eruption in YMR.

- Pumice is generally intact, subround to subangular, with an average (n=20) maximum diameter (D_{max}) of 4.4 cm and individual D_{max} of 6.0 cm. Appears very coarse grained in relation to potential source vents.

- New single-crystal $^{40}Ar/^{39}Ar$ dates of anorthoclase (n=12) give new age of 9.1±0.3 Ma and initial $^{40}Ar/^{39}Ar$ of 294±3. Previous zircon fission-track date of 6.3±0.8 Ma most likely inaccurate.

- New date correlates with 9.2–9.4 Ma Black Mountain Caldera eruptions. Similar alkaline mineralogy supports temporal correlation.

- Verifies conclusion for no post-caldera silicic eruptions in YMR magma system

CURRENT INFORMATION SHOWS SILICIC VOLCANISM DOES NOT NEED TO BE CONSIDERED IN EVALUATING PROBABILITY & CONSEQUENCES OF YMR IGNEOUS ACTIVITY

ATTACHMENT 7

PROBABILITY OF VOLCANISM IN THE YUCCA MOUNTAIN REGION AND DISRUPTION OF THE PROPOSED REPOSITORY

NRC DWM Program Element Manager - John Trapp

CNWRA Element Manager - H.L. McKague

PRESENTED BY

CHUCK CONNOR

February 25, 1997

CNWRA Contributors

C. Connor, M. Conway, D.Ferrill, S. Greenon, B. Henderson, B. Hill, M. Jarzemba, P. La Femina, S. Magsino, L. McKague, R. Martin, J. Stamatakos

SUMMARY OF GEOLOGIC SETTING OF VOLCANISM

PROBABILITY MODELS OF VOLCANISM SHOULD ACCOUNT FOR THE FOLLOWING FEATURES:

- CLUSTERED VOLCANISM IN CRATER FLAT
- ASSOCIATION OF VOLCANOES AND FAULTS
- PREVALENCE OF NE-TRENDING VENT ALIGNMENTS
- LOW AND PERSISTENT RECURRENCE RATE

OUTLINE

- Nonhomogeneous Poisson Probability Models
- Integrating Geologic Structure Into Probability Models
- Dike Length And Probability Of Intersection
- Conclusions

Basic Procedure for Probability Calculations

$$\lambda_n * \lambda_s^w * \lambda_d$$

Estimate nonhomogenous model

Estimate of structures that enhance magma ascent, weighted by *w*

Estimate of dike geometries that can intersect repository

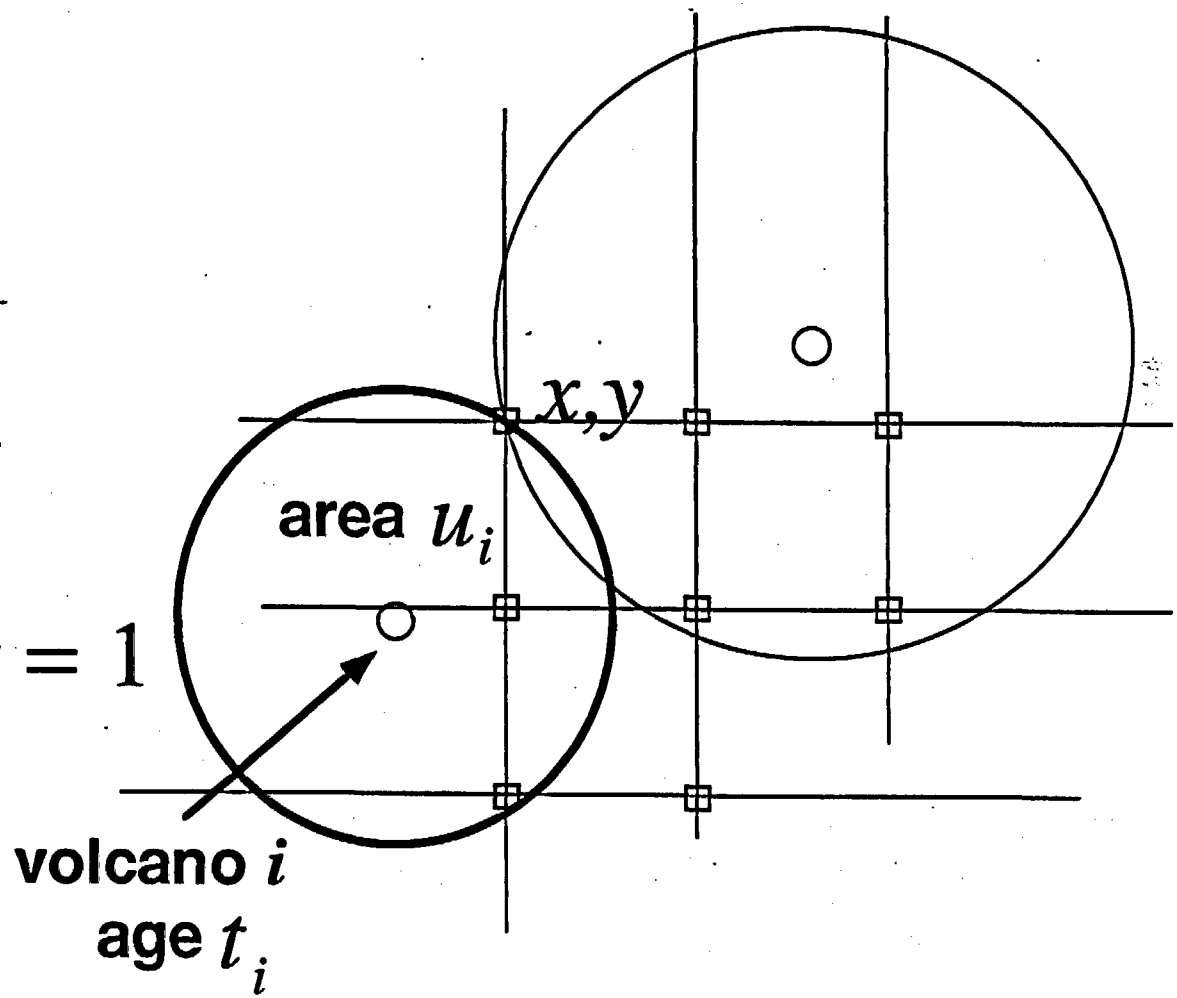
$$* \ \lambda_t \longrightarrow \text{P[Volcanic Disruption]}$$

Estimate of the regional recurrence rate of volcanism

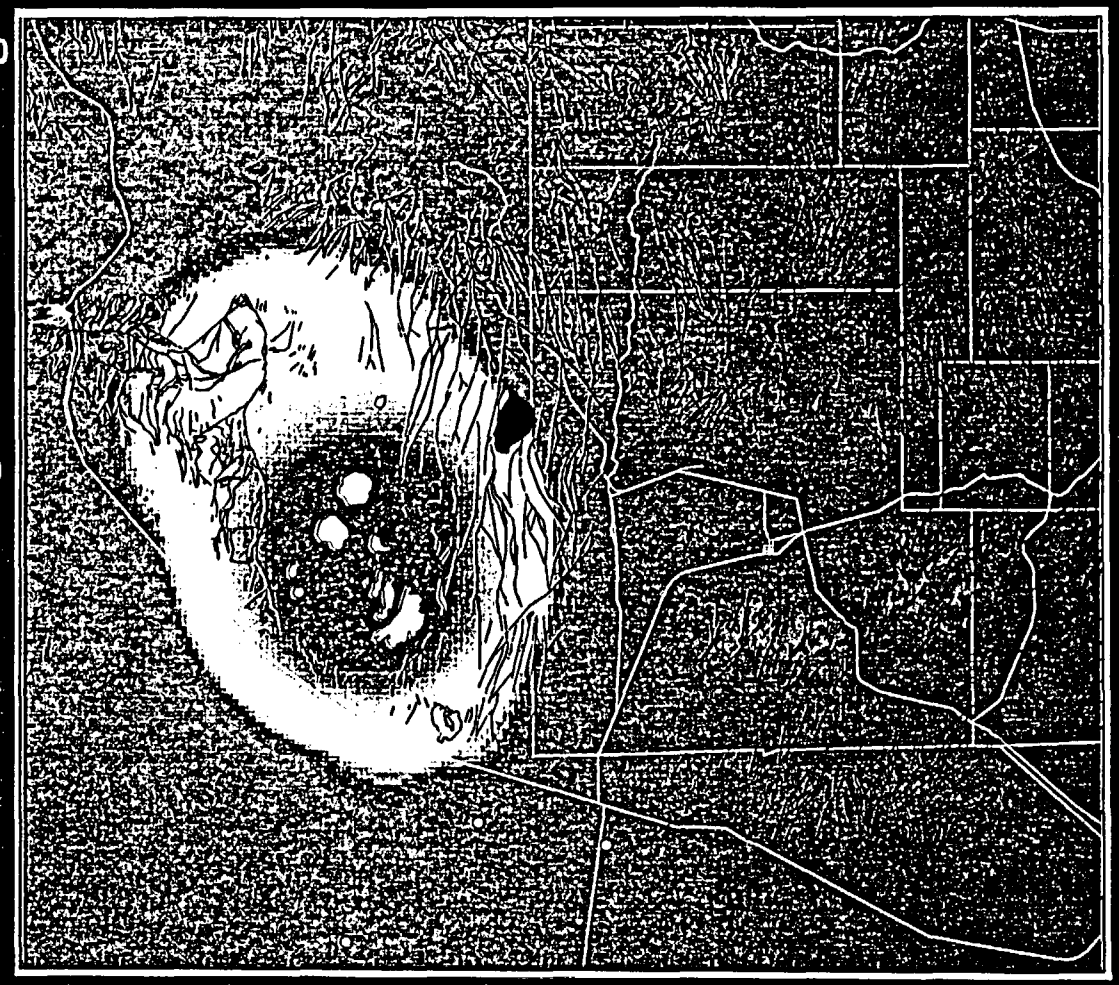
ESTIMATING SPATIAL INTENSITY OF VOLCANISM

$$\lambda_n(x,y) = \frac{m}{\sum_{i=1}^{m} u_i t_i}$$

$$\int_X \int_Y \frac{1}{k_1} \lambda_n(x,y)\, dy dx = 1$$



Comparison of Near–Neighbor Probability Model, Faults, and Volcano Locations in the Yucca Mountain Area

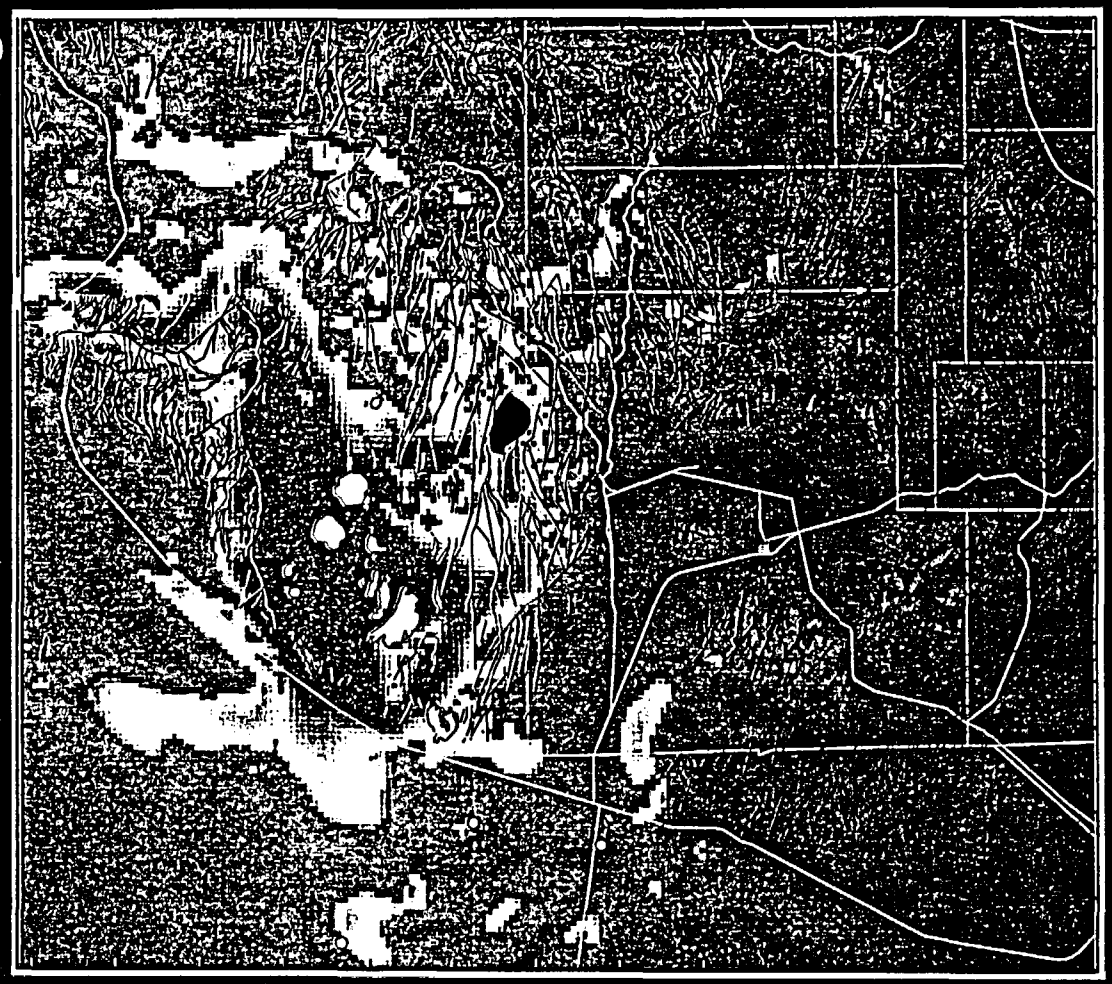


DISCRETIZING THE HORIZONTAL GRAVITY GRADIENT

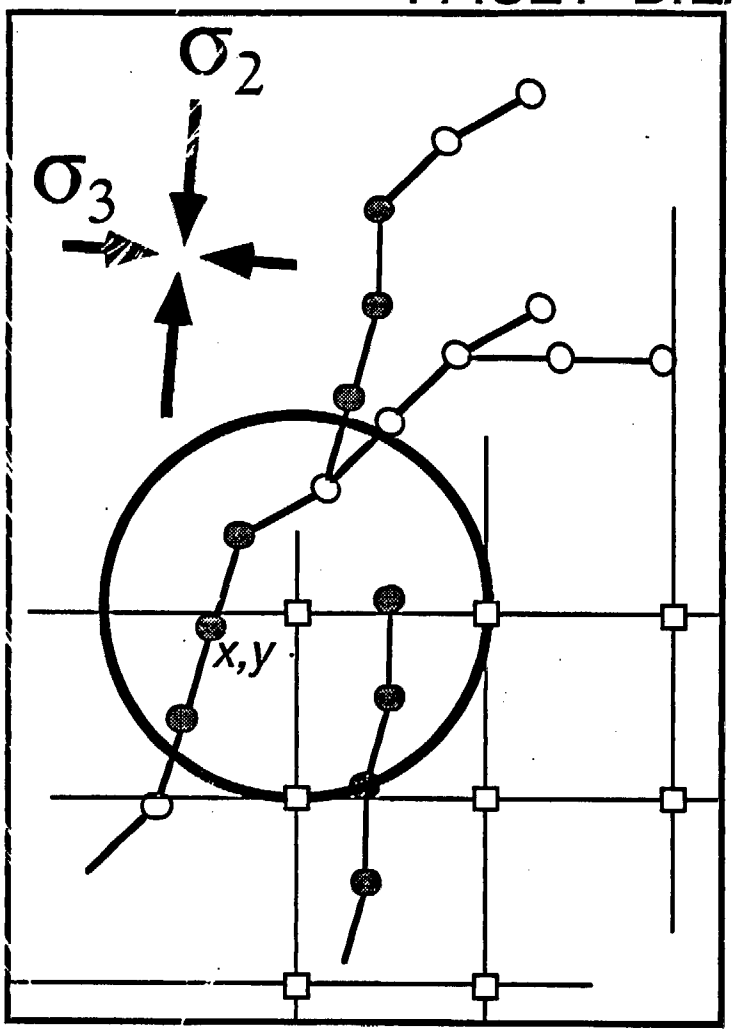
$$s(x,y) = \sqrt{\left[\frac{\partial g}{\partial x}\right]^2 + \left[\frac{\partial g}{\partial y}\right]^2}$$

$$\int_X \int_Y \frac{1}{k_2} s(x,y)\, dy dx = 1$$

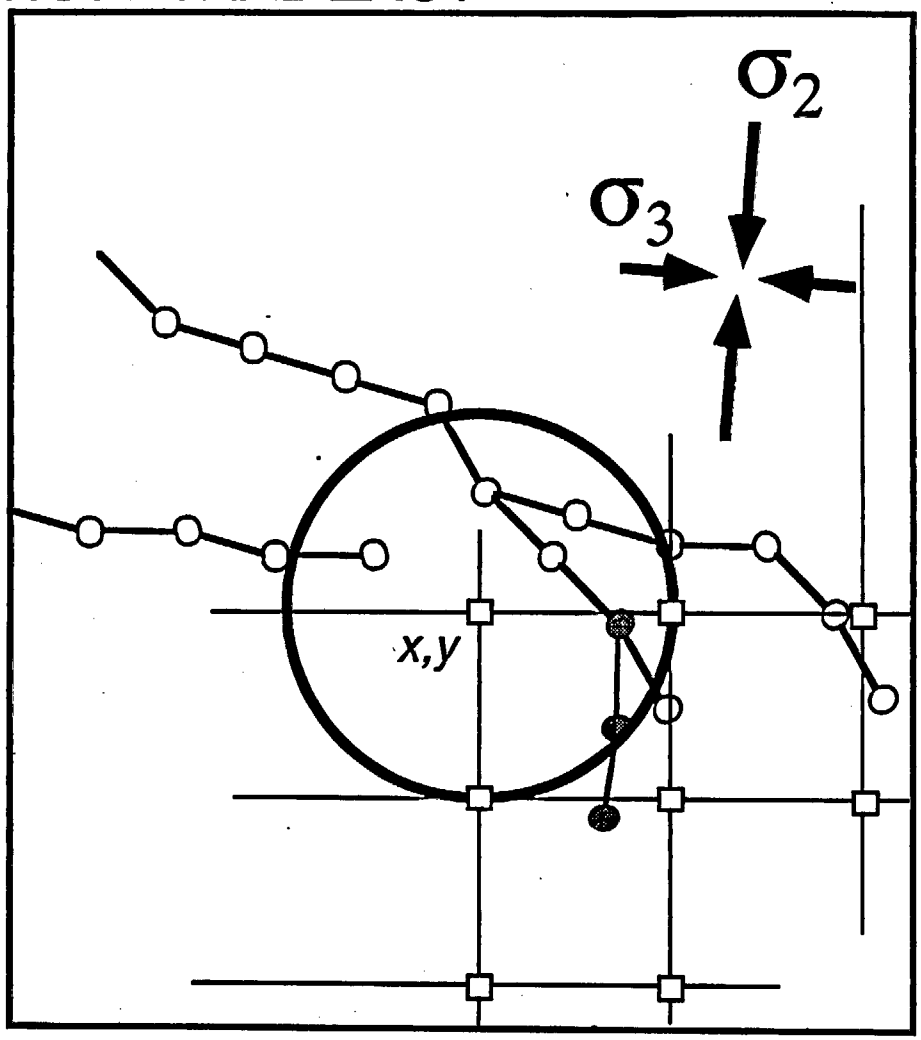
Near–Neighbor Probability Model Weighted by Horizontal Gravity Gradient



FAULT DILATION TENDENCY



Greater Potential for Volcanism at (x,y)



Less Potential for Volcanism at (x,y)

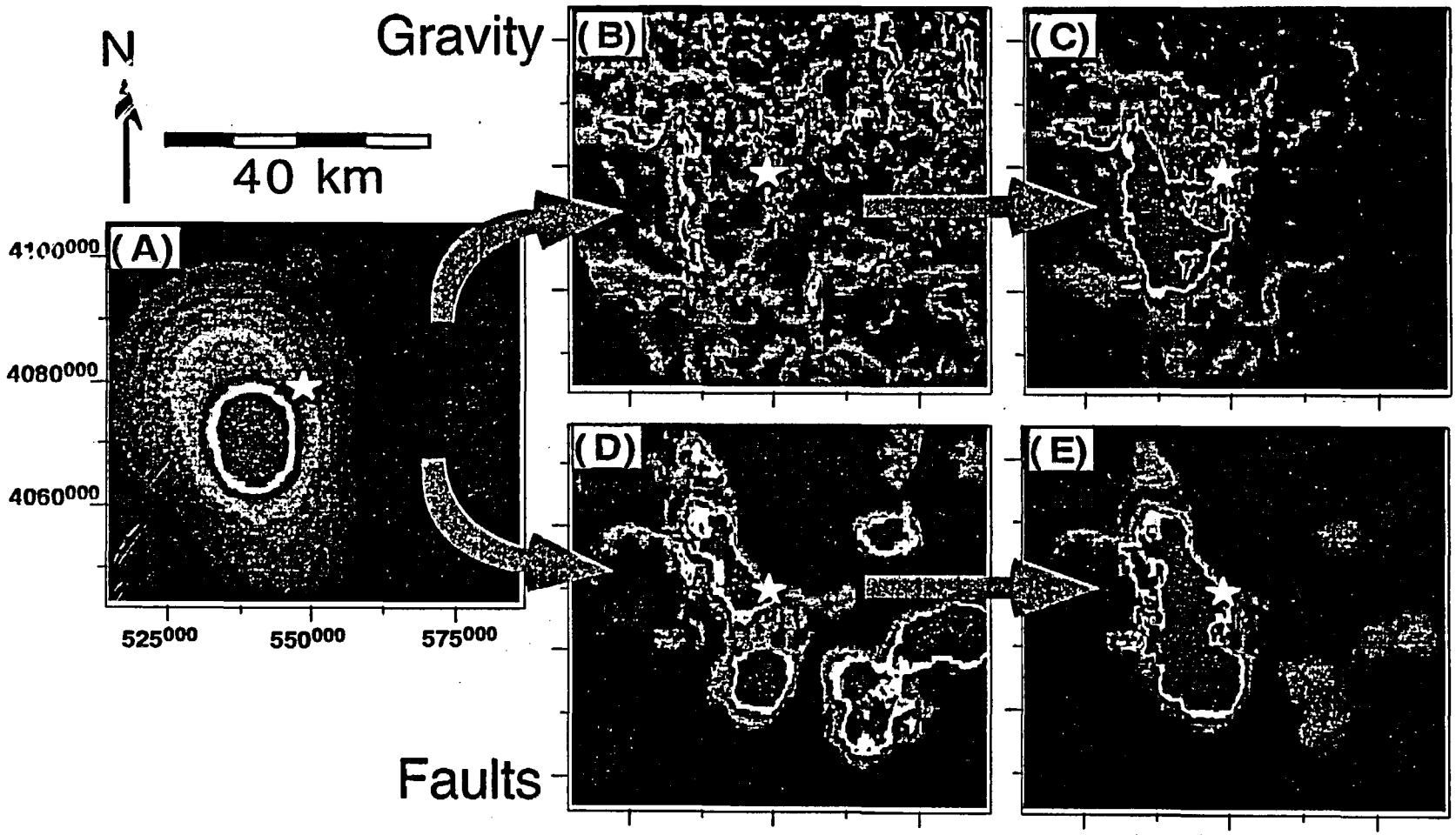
DISCRETIZING FAULT DILATION TENDENCY

$$t(x,y) = \frac{n_t(x,y)}{\sum_X \sum_Y n_t} - \frac{n_f(x,y)}{\sum_X \sum_Y n_f}$$

$$s(x,y) = \begin{cases} t(x,y), & t(x,y) > n_k \\ n_k, & 0 < t(x,y) < n_k \\ 0, & t(x,y) < 0 \end{cases}$$

$$\int_X \int_Y \frac{1}{k_2} s(x,y)\, \mathrm{d}y\mathrm{d}x = 1$$

INTEGRATED VOLCANO-STRUCTURE PROBABILITY



Nonhomogeneous probability models (A) are convolved with the amplitude of the horizontal gravity-gradient (B), and the density of high-dilation tendency faults (D) to make geologically dependent probability maps (C and E).

PROBABILITY OF A DIKE INTERSECTING THE REPOSITORY

$$h_1 = \frac{\min\{U[d_1, d_2]\}}{2} \qquad h_2 = \frac{\max\{U[d_1, d_2]\}}{2}$$

$$d_L^L(x,y) = \frac{(h_2 - d(x,y))}{(h_2 - h_1)}$$

$$\lambda_d(x,y) = \begin{cases} 1, \ d(x,y) \le h_1 \\ d_L(x,y), h_1 < d(x,y) < h_2 \\ 0, \ h_2 \le d(x,y) \ \textit{or} \ d(x,y) \ \textit{is undefined} \end{cases}$$

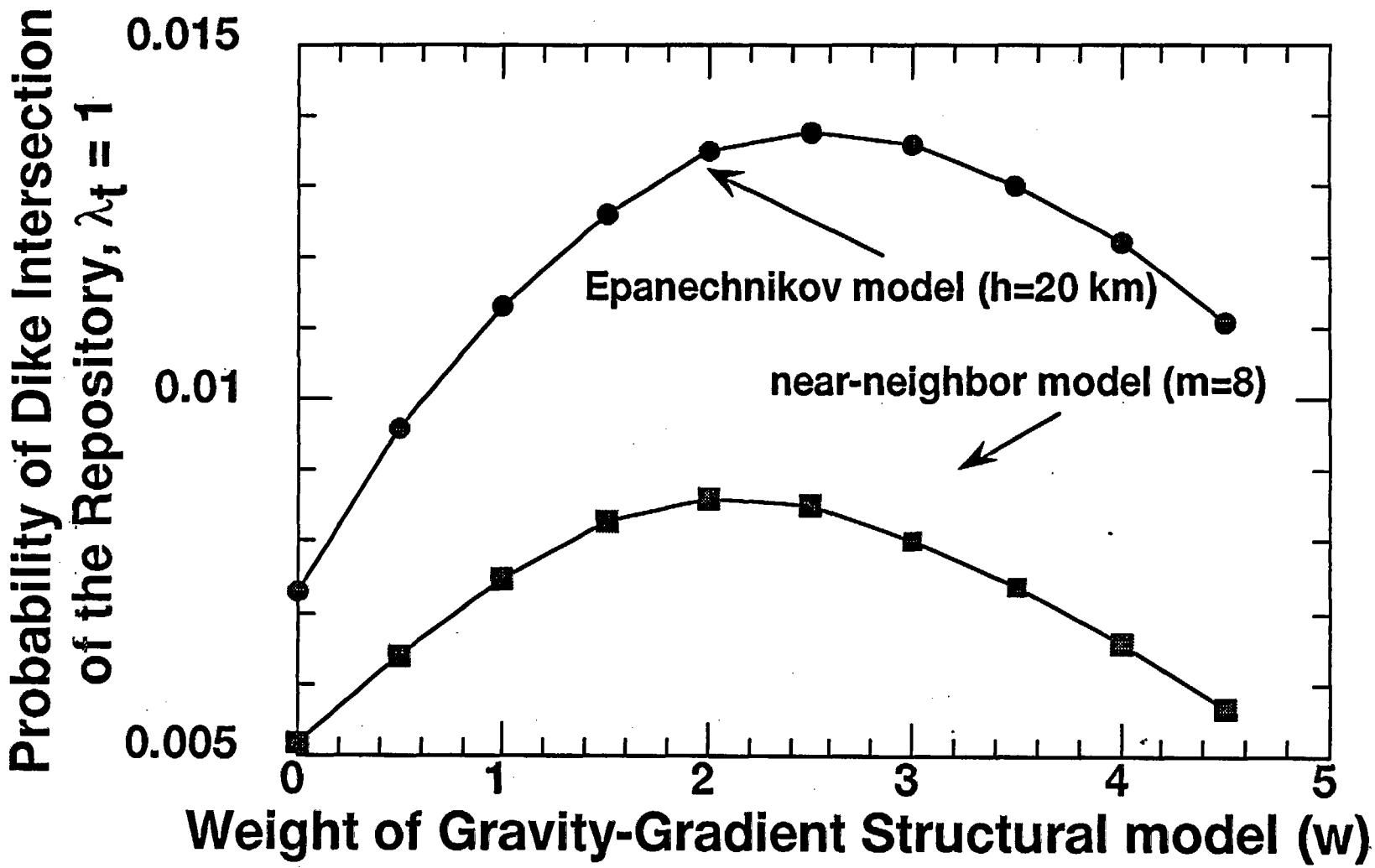
$$h_1 = 500\ m$$
$$h_2 = 2500\ m$$

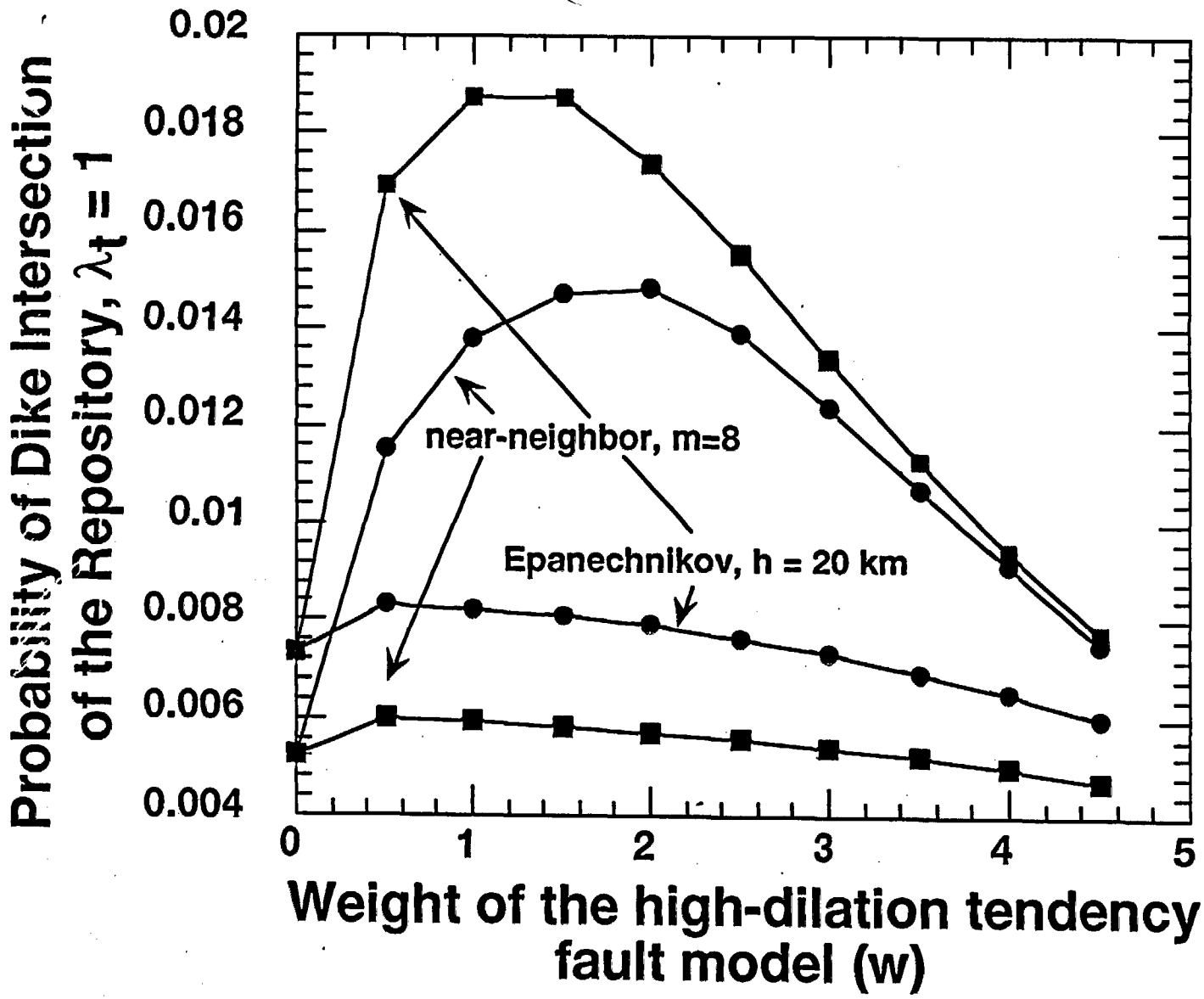
CALCULATING PROBABILITY

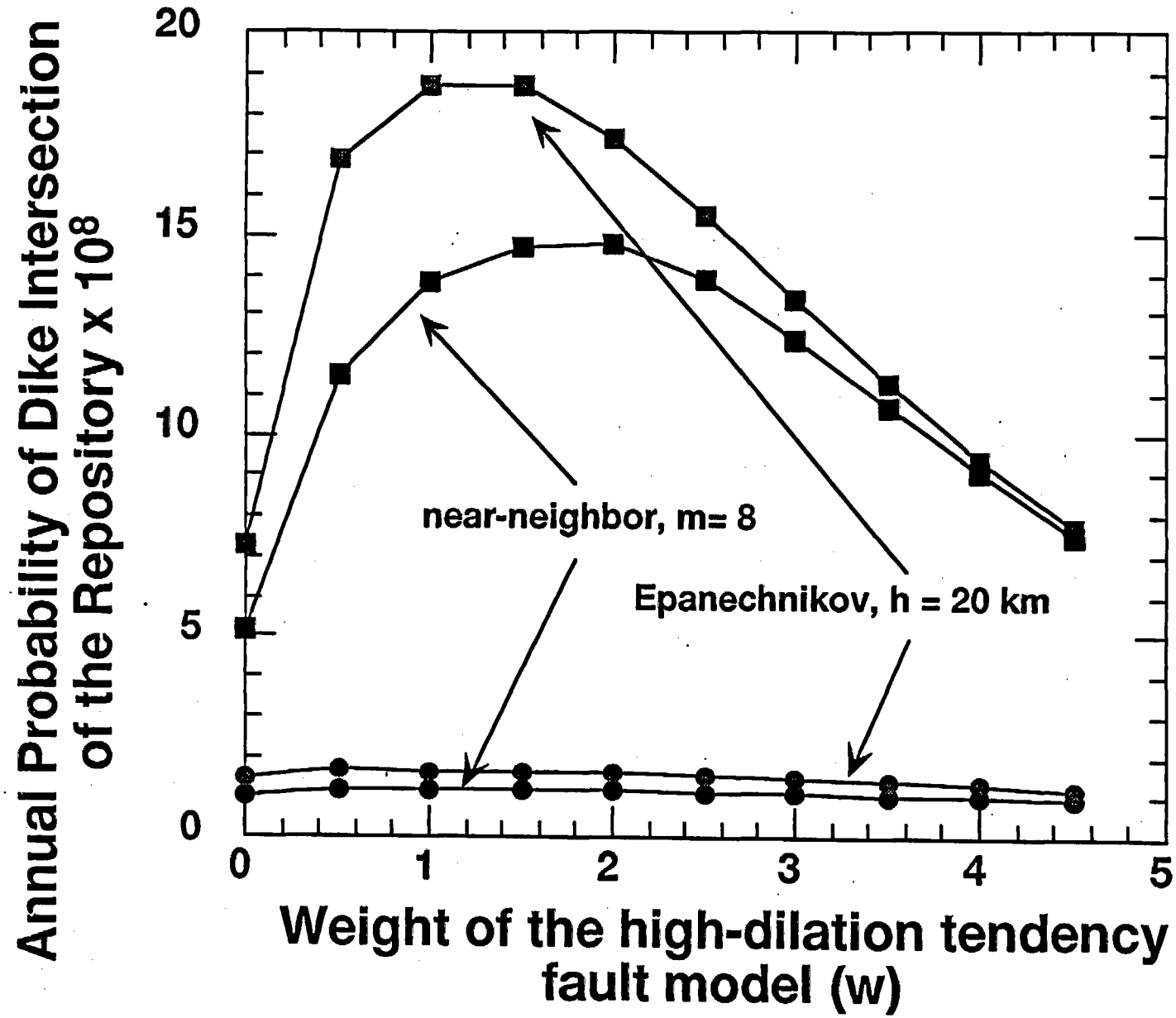
$$\lambda_s(x,y) = \frac{1}{k_3}\left(\lambda_n(x,y) \cdot s(x,y)^w\right), \quad 0<w$$

$$P[N \geq 1] =$$

$$1 - exp\left[-t\,\lambda_t \int_X \int_Y \lambda_s(x,y)\,\lambda_d(x,y)\,dy\,dx\right]$$


Probability of Dike Intersection of the Repository, $\lambda_t = 1$
0.015
0.01
0.005
0
1
2
3
4
5
Weight of Gravity-Gradient Structural model (w)
Epanechnikov model (h=20 km)
near-neighbor model (m=8)


Probability of Dike Intersection of the Repository, $\lambda_t = 1$
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0
1
2
3
4
5
Weight of the high-dilation tendency fault model (w)
near-neighbor, m=8
Epanechnikov, h = 20 km


Annual Probability of Dike Intersection of the Repository x 10^8
20
15
10
5
0
0
1
2
3
4
5
Weight of the high-dilation tendency fault model (w)
near-neighbor, m= 8
Epanechnikov, h = 20 km

CONCLUSIONS

- Plio-Quaternary basaltic volcanoes near YM correlate well with high-dilation tendency faults and regionally with vertical displacements in basement, indicated by gravity gradients

- Including structural control in these volcanic hazard models increases the probability of volcanic disruption of the proposed repository compared to models that do not include structure

- These models indicate a range of probability of volcanic disruption of the repository between 1×10^{-7} and 1×10^{-8} /yr

ATTACHMENT 8

CNWRA INVESTIGATIONS OF IGNEOUS ACTIVITY CONSEQUENCES ON REPOSITORY PERFORMANCE

FIN D1035
NRC DWM Program Element Manager: J.S. Trapp
CNWRA Element Manager: H.L. McKague

Presented at the February 25-26,1997
Technical Exchange on Igneous Activity

by

Dr. Brittain Hill
Research Scientist

CNWRA Contributors
C. Connor, M. Conway, S. Greenan, B. Henderson, B. Hill,
M. Jarzemba, P. LaFemina, L. McKague, R. Martin

CONCEPTUAL MODEL FOR WASTE INCORPORATION INTO ERUPTION

- MAGMA: 1100 °C, density 2600 kg/m^3, viscosity 10–100+ Pa s (sucrose 1000 Pa s @ 100°C), velocity 1 m/s initial to 100 m/s eruption, acidic gas.

- WASTE PACKAGE BEHAVIOR UNDER MAGMATIC CONDITIONS POORLY KNOWN
  - Waste package fails between 10^{-2} s to 1 year from simple thermal effects of magma. This is the duration range for most basaltic eruptions.

- WASTE BEHAVIOR UNDER ERUPTION CONDITIONS POORLY KNOWN
  - Waste particles incorporated into ascending magma. Volatile expansion, temperature, and shear may further reduce particle grain-size.

- DISPERSAL CAPABILITIES OF YMR VOLCANOES POORLY KNOWN
  - Waste ejected ballistically from volcano vent or convectively in the eruption column and transported downwind in eruption plume.

Data, Models, and Assumptions Are Necessary to Evaluate Dose Associated with Volcanic Eruption Through Repository

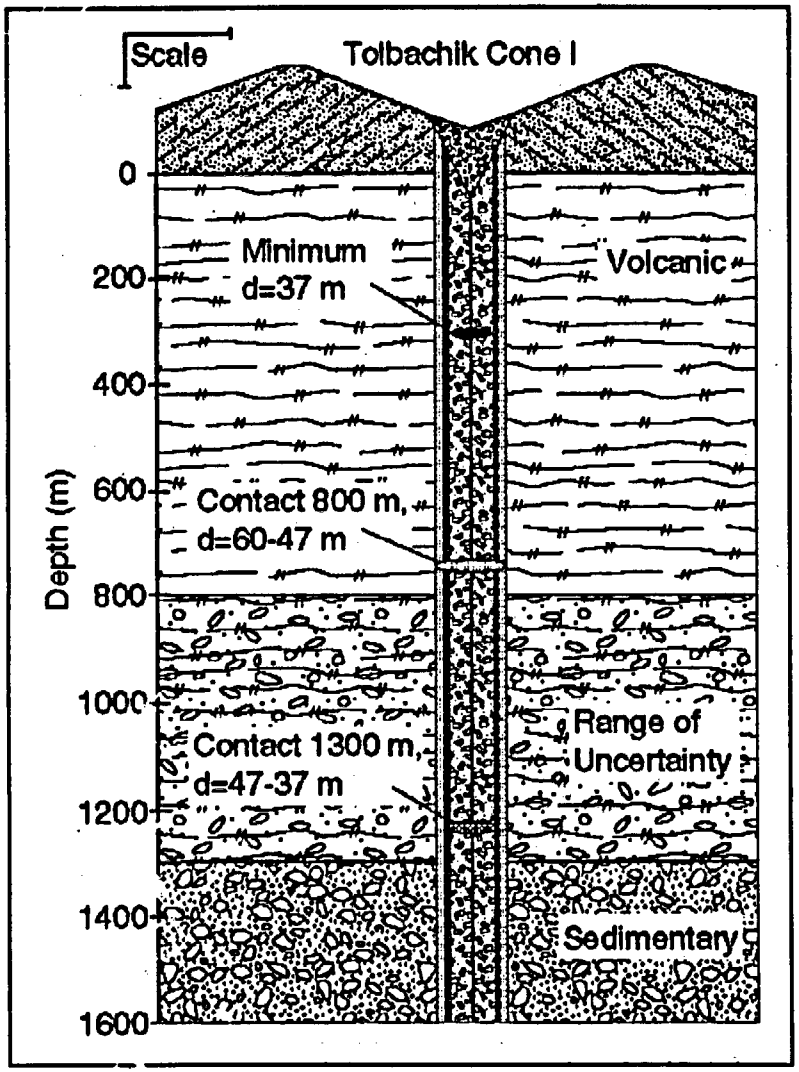
ANALOG VOLCANISM YIELDS YMR INSIGHTS

	Avg LW	Avg CF	C1 Early	C1 Late
# of analyses	20	32	21	11
Wt. % oxides				
SiO_2	48.80	50.20	49.80	50.00
TiO_2	1.95	1.59	1.02	1.30
Al_2O_3	16.81	17.30	13.48	15.32
Fe_2O_3	2.33	2.15	3.06	3.47
FeO	8.37	7.72	6.99	6.88
MnO	0.17	0.17	0.16	0.17
MgO	5.86	5.09	9.88	7.69
CaO	8.57	8.71	11.60	9.83
Na_2O	3.62	3.41	2.44	3.14
K_2O	1.80	1.76	1.03	1.62
P_2O_5	1.22	1.10	0.25	0.35
Estimated H_2O	2	2	2	2
Estimated T (°C)	1100	1100	1200	1200
Density (kg m^{-3})	2590	2570	2600	2640
Viscosity (Pa s)	17	30	4	6
Crystal Fraction	0.03	0.03	0.03	0.03
Viscosity with crystals (Pa s)	20	34	5	7

YMR data from Hill and Luhr (unpub. res), 1975 Tolbachik from Volynets et al. (1983).

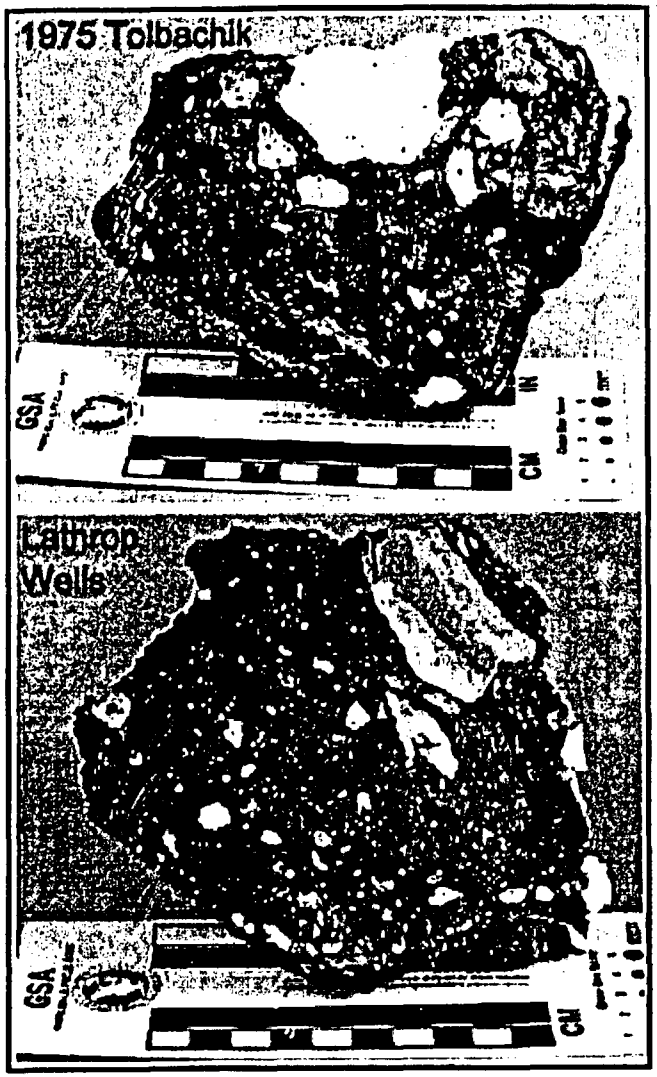
- 1975 Tolbachik eruption in Kamchatka, Russia, analogous for processes relevant to understanding Quaternary YMR volcanoes.
- Extensional tectonic settings with magma equilibration depths around 40 km, remarkably similar basalts derived from hydrous mantle lithosphere
- - Cone 1 = 0.14 km^3 DRE
  - Lathrop Wells = 0.14 km^3 DRE
  - Quat YMR = 0.06-0.23 km^3 DRE
  - 1975 Tolbachik = 0.45 km^3 DRE
- Insights into poorly preserved YMR eruption deposits and processes

SUBSURFACE AREA OF DISRUPTION



- 12 hr at end of 1975 Tolbachik Cone 1 eruption, 2.8×10^6 m^3 of shallow subsurface rock disrupted.
- Main contact between volcanic and sedimentary rocks 800-1300 m, water table at 500 m
- Volume of subsurface rock equals widening conduit from initial 1-3 m diameter to 49±7 m diameter
- Late-stage reduction in magma flow rate allowed dilation of fractures below 500-m-deep water table, aiding brecciation
- Sparse rock-ash on cone, but abundant (1-2%) xenoliths on cone flanks

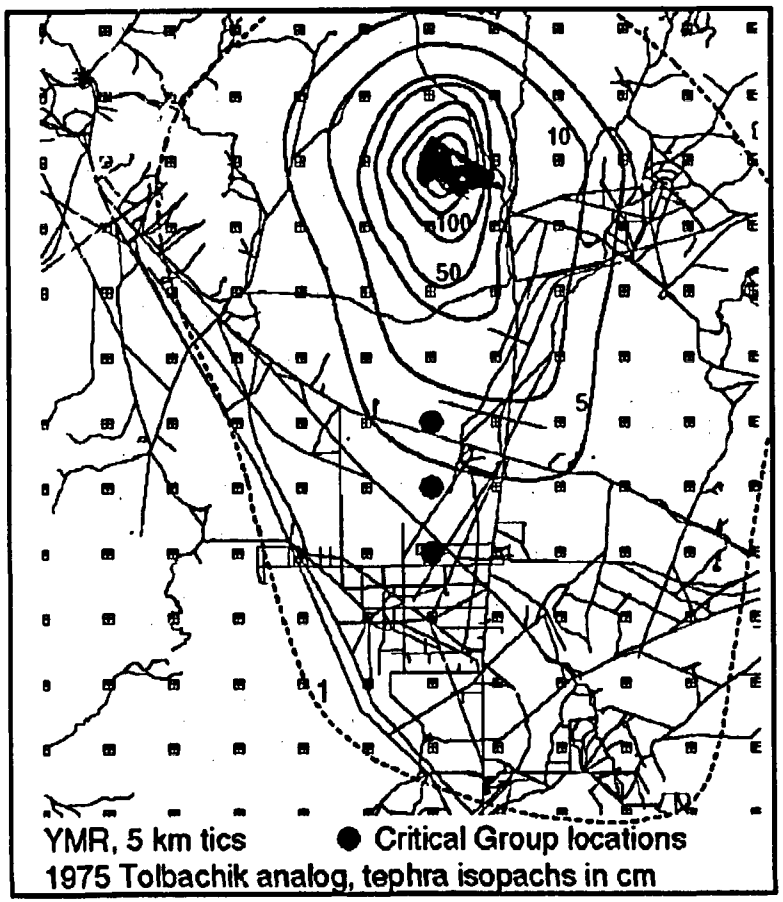
SUBSURFACE AREA OF DISRUPTION



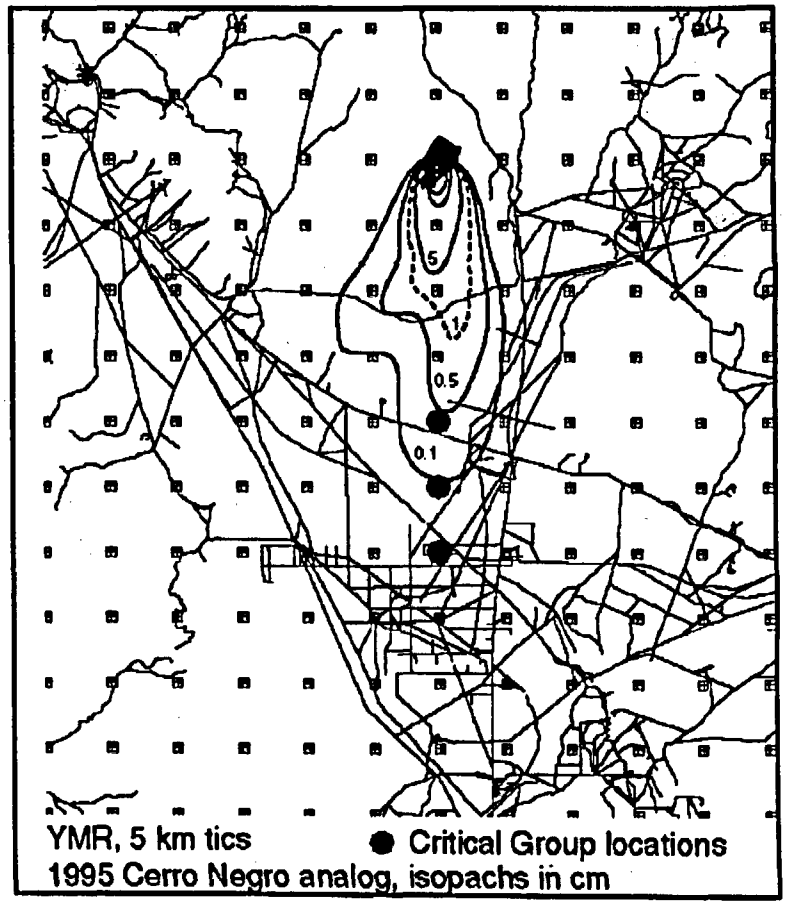
- Upper part of tephra fall deposit at Lathrop Wells and all other YMR volcanoes eroded
- Proximal xenoliths unusually abundant on outer flanks of Lathrop and Little Black Peak
- Same type of unusual polylithologic, polythermal volcanic pyroclasts at Lathrop and Tolbachik produced during a late-stage disruptive event (Figure)
- Both volcanoes disrupted similar range of crustal sections, up to 0.5–2 km deep
- Scale of disruption for Lathrop Wells most likely comparable to 1975 Tolbachik. May disrupt 4–10 waste packages if similar event occurs in 83 MTU/acre repository.

TRANSPORT OF MATERIAL FROM BASALTIC VOLCANOES

Size-range of analog eruptions superimposed on YMR site, wind to south.

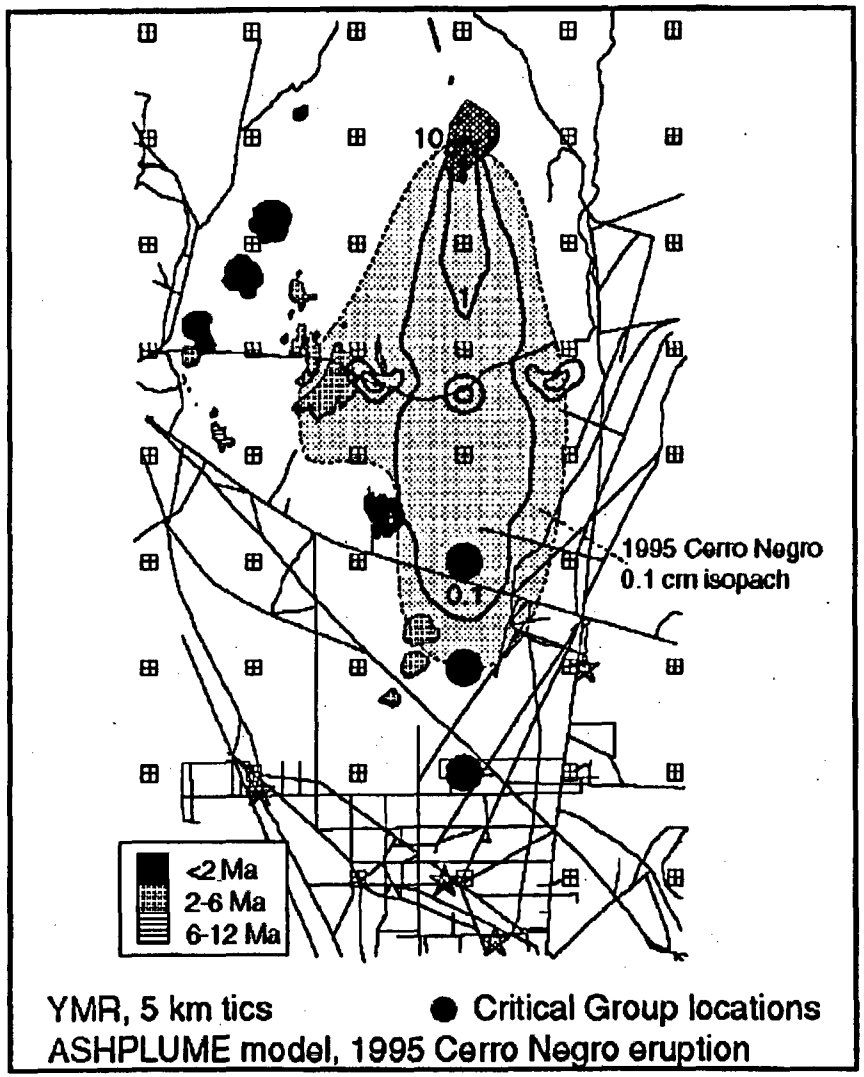


WIND



1 cm isopach shown in dashed line. Tolbachik (0.45 km^3), Cerro Negro (0.008 km^3)

MODELING TEPHRA DISPERSION WITH ASHPLUME



- Dispersion model of Suzuki (1983)
- Accounts for vertical and lateral dispersion of particles
- Modeling 1995 Cerro Negro, calculated deposit thickness very sensitive to Wind Speed
- Moderately sensitive to column height, particle diameter & density
- Model reproduces measured deposit thicknesses within 50% at 20–30 km
- ASHPLUME used to calculate dose from volcanic eruptions

DOE/NRC Points of Agreement and Proposed Path to Resolve Subissue of Probability Igneous Activity Technical Exchange - February 25-26, 1997

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2. DOE and NRC agree that based on current information, silicic volcanism need not be evaluated.

3. DOE agrees to consider evaluating new data such as:

   - the size and volume of Little Cone
   - the number of events at Anomaly A

   through hazard sensitivity studies.

4. NRC believes that an annual probability of 10^{-7}/yr is a reasonably conservative upper bound for extrusive events. There are differing views on the lower bound. DOE considers that the PVHA provides a defensible basis for characterizing the probability of disruption (includes both intrusive and extrusive magmatic events). The probability distribution function (PDF) has an upper bound frequency of 10^{-7}, a lower bound of 10^{-10}, and a mean of 1.5×10^{-8} per year. DOE agrees to explain how the PDF for the probability of disruption will be used in performance assessment, including sensitivity studies, recognizing NRC's comments.

5. DOE and NRC agree that:

   A. Volcanism is of regulatory interest and its probability and consequences will be considered.
   B. If determined to be significant with respect to repository performance, the effects of volcanism will be included in the total system performance assessment.

6. The treatment of consequences outlined by DOE that includes extrusive magmatic events (cone and dike formation) and intrusive magmatic events (sill and dike formation) with both direct and indirect effects is generally appropriate at the level of detail provided.

7. DOE and NRC agree that there is uncertainty in consequence analysis for magmatic waste package interactions and will be evaluated.

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ANNUAL INDIVIDUAL DOSE ESTIMATES FROM "PRELIMINARY" PERFORMANCE CALCULATIONS

Tim McCartin
US Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

Presented at:

Igneous Activity Technical Exchange
February 25 & 26, 1997

ATTACHMENT 9

CONTEXT OF DOSE ESTIMATES

IPA Phase 2

Initial incorporation of dose assessment capability in anticipation of dose based standard

TSPA '95

Preliminary inclusion of a peak dose calculation in response to NAS Recommendation

NRC Staff Evaluation of NAS Recommendations

Identification of implementation issues with long term dose estimates and exposure scenario (reference biosphere and critical group)

IPA Phase 2

BASIC ASSUMPTIONS

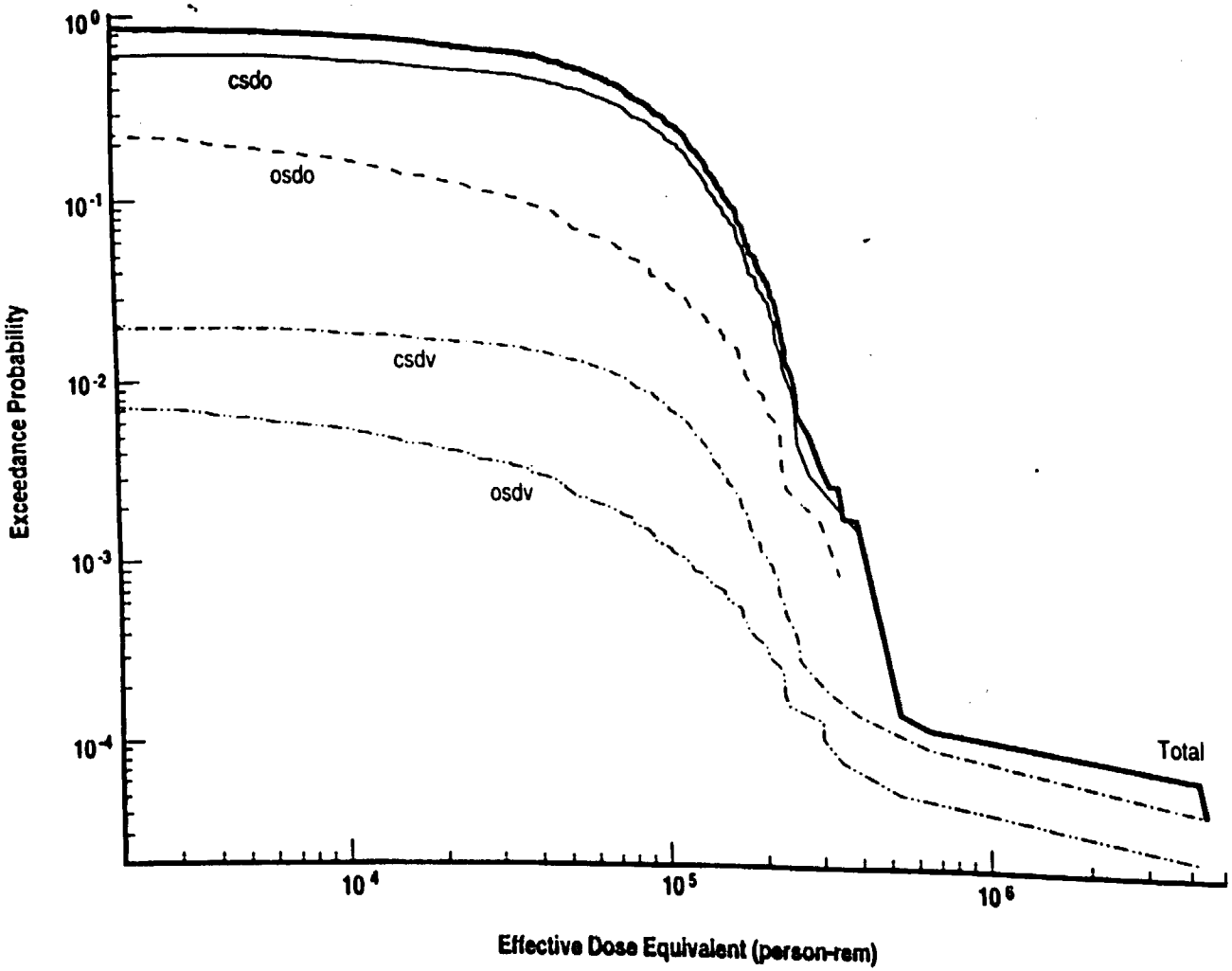
- Disturbed and undisturbed performance evaluated
  - emphasis on integrated release rather than exposure calculation

- Population dose calculated (quasi-annual individual dose backed out of population dose)
  - farm family of 3
  - contaminated beef feeds 177/year
  - air pathway considers population of 22,000 (within 100 km of YM)
    (Gaussian plume model used to disperse releases in the air pathway)

- area of interception of ascending magma used to determine amount of waste affected
  - intrusive (early failure of containers)
  - extrusive (direct release, 30% of which is available for air pathway)

- Probability of event in vicinity of YM is 1.5×10^{-4} over 10,000 years
  - one volcanic event occurs between 0 and 10,000 years

NRC IPA Phase 2

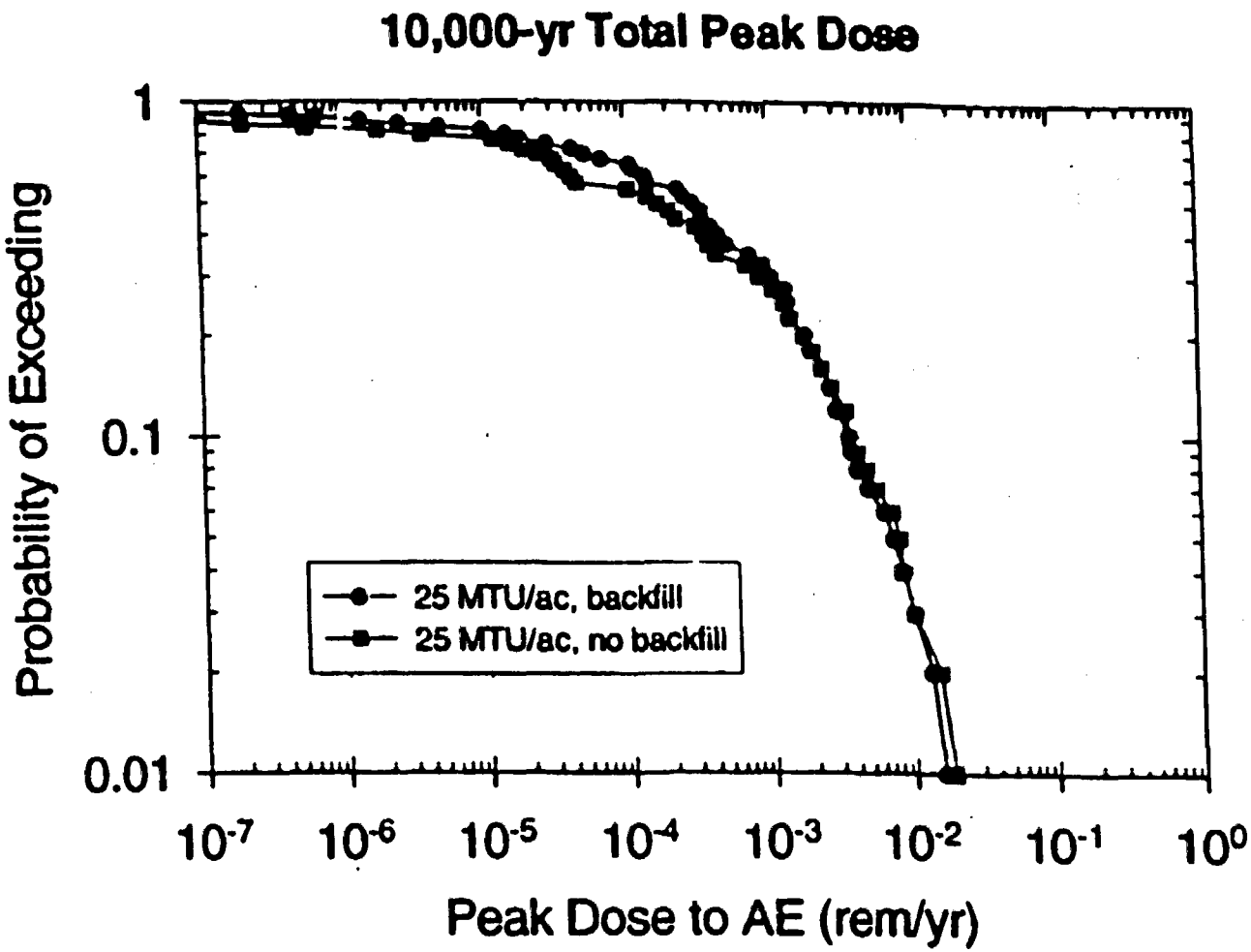


Total CCDF for Effective Dose Equivalent from significant scenarios

BASIC ASSUMPTIONS

- Undisturbed performance only
  - volcanism not considered quantitatively
  - TSPA 91 considered direct release to surface from volcanic event
  - TSPA 93 considered indirect effects of volcanic event
- Drinking water dose at 5 km

DOE TSPA '95



CCDF of peak annual individual dose at 5 km down gradient (with and without backfill, high infiltration, 25 MTU/acre)

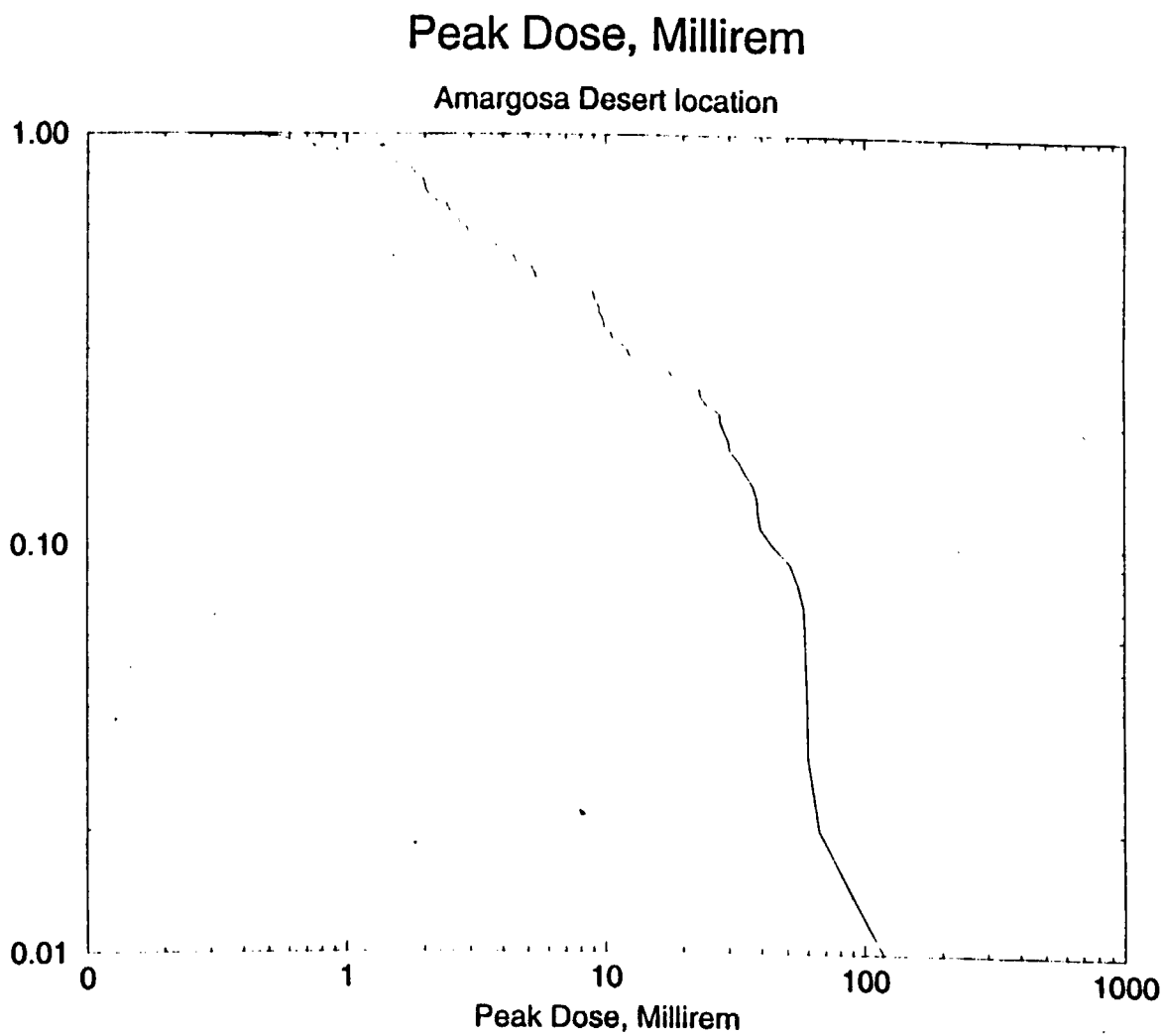
NRC Staff Evaluation of NAS Recommendations

BASIC ASSUMPTIONS

- Nominal base case analyzed
  - probability near unity
  - peak dose (up to 1 million years)
  - compliance at 5 km (drinking water pathway) and 30 km (all pathways)
  - average member of critical group approach for individual dose

- Extrusive volcanism analyzed
  - undisturbed performance, extrusive volcanism, and human intrusion (analyzed separately)
  - compliance at 20-30 km (all pathways)
  - average member of critical group approach for individual dose
  - consideration of magmatic interaction with waste and deposition of ash

NRC Evaluation of NAS



Uncertainty analysis (100 realizations) of annual individual dose at 30 km (all pathways) down gradient

Individual Dose Comparison

CALCULATION	MEDIAN DOSE	90th PERCENTILE
TSPA 95 (5 km, drinking water)	.4 mrem	4 mrem
NRC NAS Nominal (30 km, all pathway)	4.4 mrem	40 mrem

ATTACHMENT 10

CNWRA DOSE CALCULATIONS FOR VOLCANIC DISRUPTION OF THE PROPOSED REPOSITORY

FIN D1035
NRC DWM Program Element Manager: J.S. Trapp
CNWRA Element Manager: H.L. McKague

Presented at the February 25-26,1997
Technical Exchange on Igneous Activity

by

Dr. Brittain Hill
Research Scientist

CNWRA Contributors
C. Connor, B. Hill, M. Jarzemba, R. Manteufel

CURRENT DOSE CALCULATIONS FOR VOLCANIC ERUPTIONS

BASIC ASSUMPTIONS

- Volcanic eruption occurs through repository between +200 and +10,000 yr
- One canister fails and all waste (10 MTU) available for magmatic transport
- Wind blows to south 14% of the time
- Critical group located 20–30 km south of repository
- Current TPA approach (DCF, GENII-S, etc.) used for dose calculations

CRITICAL PROCESSES

- Behavior of ascending magma in disturbed geologic setting
  - *Under investigation, assumed non-disturbed behavior*
- Canister response to ascending magma
  - *Failure assumed based on initial analysis*
- Waste particle-size distribution
  - *Mean values 10, 1, and 0.01 mm, log-triangular range ±1 log unit*
- Waste incorporation mechanisms into magma
  - *Tephra diameter must be 10x, 5x or 2x waste diameter to incorporate*
- Dispersal capabilities of YMR volcanoes
  - *As observed at historically active analogs, using ASHPLUME*

EVALUATE SENSITIVITY TO WASTE PARTICLE-SIZE AND INCORPORATION FACTORS

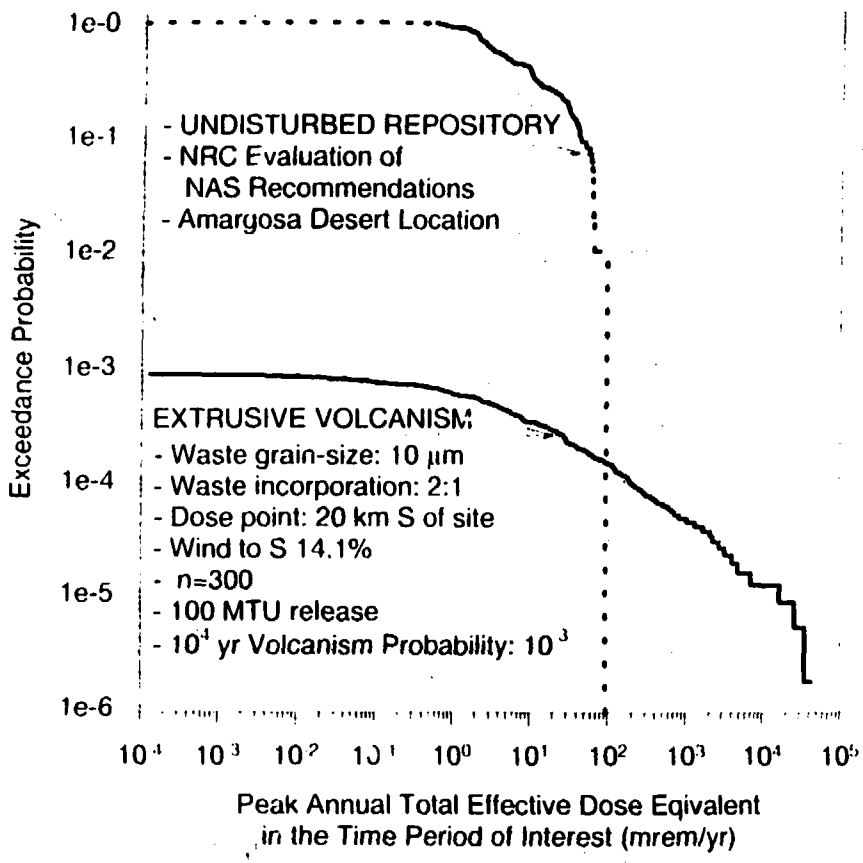
RESULTS OF 300 SIMULATIONS EACH, 10 MTU WASTE AVAILABLE FOR TRANSPORT
MEAN ANNUAL PEAK DOSE, 1 STANDARD DEVIATION (MREM/YEAR)
LOG-NORMAL DISTRIBUTIONS

Parameters sampled stochastically: Eruption power & duration (column height, eruption rate, mass), column shape, time, wind speed, tephra diameter

PARAMETER SENSITIVITY EXAMINED	CRITICAL GROUP LOCATION 20 KM	CRITICAL GROUP LOCATION 30 KM
• 0.01 mm diameter, 2x incorporation	50, 300	7, 40
• 0.01 mm diameter, 10x incorporation	40, 300	4, 40
• 1 mm diameter, 2x incorporation	9, 90	0.2, 3
• 1 mm diameter, 10x incorporation	0.3, 3	10^{-4}, 10^{-3}
• 10 mm diameter, 2x incorporation	10^{-3}, 10^{-2}	10^{-8}, 10^{-7}
• 10 mm diameter, 10x incorporation	10^{-18}, 10^{-17}	$\ll 10^{-36}$

CURRENT DOSE ASSESSMENT FOR VOLCANIC ERUPTIONS

Comparison of Current Undisturbed Repository Performance with Extrusive Volcanism



Extrusive volcanism does not consider potential igneous activity effects on total-system, such as canister degradation or hydrologic flow and transport.

CCDF shows mean values are reasonably conservative for these calculations

Current calculations show this mean is ≤50 mrem/yr

- Vent widening may disrupt 10 canisters, thus 50 × 10 canisters = 500 mrem/yr

Current CNWRA probability models range to 10^{-3} for 10^{4} years

Risk = [Volcanism, 10^{-3}–10^{-4}, 500 mrem/yr]

Still to consider: Timing of eruptions, waste incorporation mechanisms, system response to thermal, chemical and mechanical loads from igneous activity, dose point locations.

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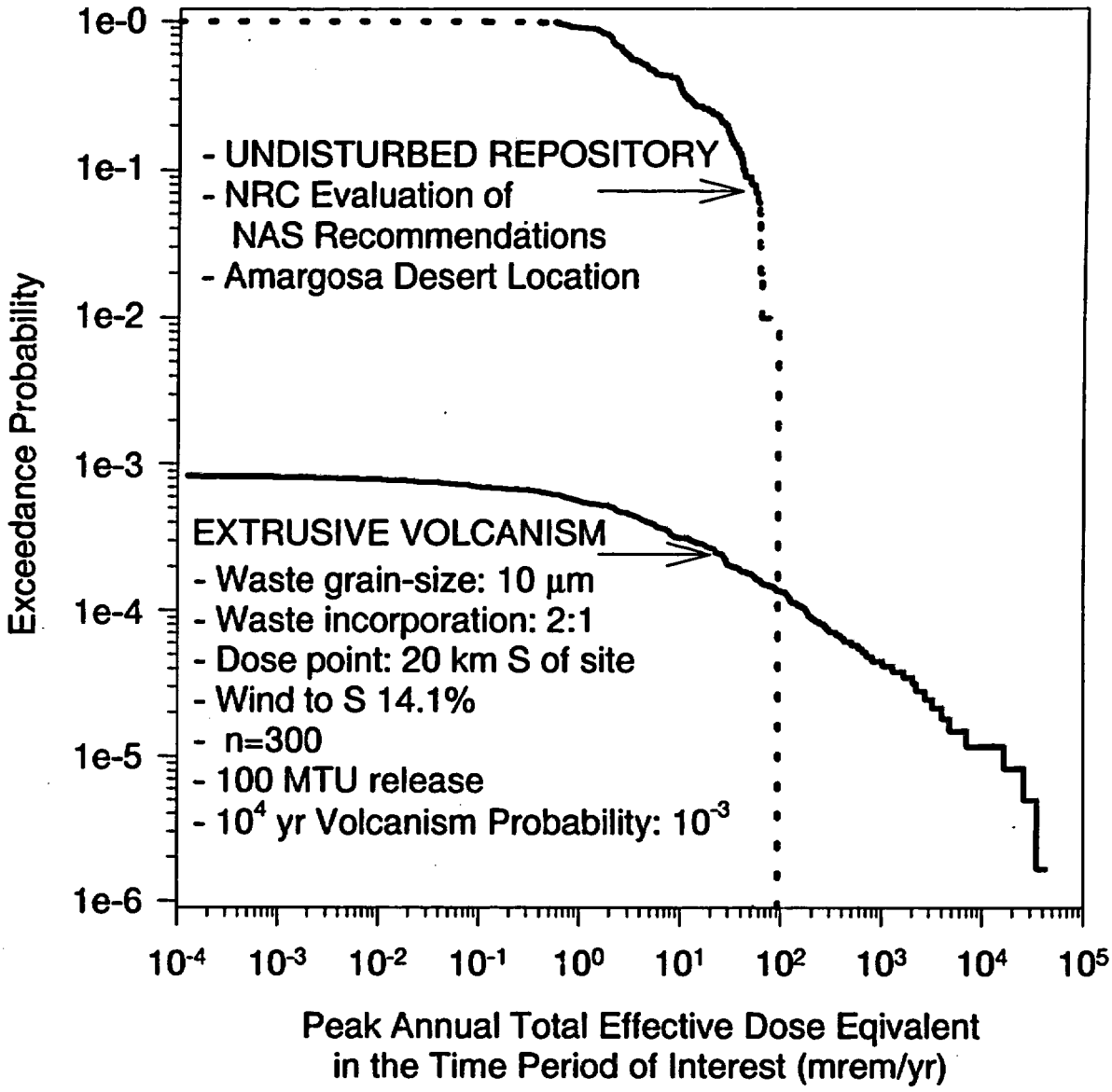
Comparison of Current Undisturbed Repository Performance with Extrusive Volcanism



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ATTACHMENT 11

DOE/NRC Points of Agreement and Proposed Path to Resolve Subissue of Probability
Igneous Activity Technical Exchange - February 25-26, 1997

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