U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

PRESENTATION TO THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: PROBABILITY CALCULATIONS

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Volcanism Studies
Yucca Mountain Project

Probability Calculations: Current Status

1. Strategy for Completing Work
   - -- Study Plan 8.3.1.8.1.1
   - -- Probability Distribution E1 and E2: Multiple Models
   - -- Option: Expert Opinion

2. Revised Calculations
   - -- After NRC review of Study Plan
   - -- Chronology and Volume Data from 8.3.1.8.5.1

3. Possible Presence of Magma Chambers
   - -- Teleseismic Tomography
   - -- Seismic Gap
   - -- Geologic Record: Magmatic Gap
   - -- Geophysical Review

4. Evaluation of Uncertainty: Probability Calculations
   - -- Perception of Unbounded Uncertainty
   - -- Upper Probability Bounds are Fixed if ....

... Constraints are Established from the <u>GEOLOGIC RECORD</u>

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Two Scenarios for Future Volcanic Activity

1. **Polycyclic Event: Recurrence of An Eruption at an Existing Center**

   Maybe a High Probability Event
   - -- dependent on resolution of chronology data

   No Effect on Yucca Mountain
   - -- seismic effects
   - -- ground water effects

Evaluated As Part of Consequence Analysis

2. **Formation of a New Volcanic Center**
   - -- finite probability of disrupting Yucca Mountain

Emphasis of Probability Calculations

Important to Discriminate Scenarios

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1. Conditional Probability

$$Pr_{DQ} = \{E3 \text{ given } E2 \text{ given } E1\}$$

E1 is the rate of formation of new volcanic centers
E2 is the probability of disruption
E3 is the probability that direct releases from magmatic disruption of the repository exceed regulatory guidelines

2. All volcanism work is structured to provide data to assess the conditional probability

   -- Data collection: Study Plan 8.3.1.8.5.1
   -- Probability calculations (E1 and E2): Study Plan 8.3.1.8.1.1
   -- Disruptive Effects (E3): Study Plan 8.3.1.8.1.2

3. Individual probability values are estimates. The significant constraints are the probability bounds.

4. 40 CFR Part 191 Appendix B "... performance assessments need not consider categories of events or processes that are estimated to have less than one chance in 10,000 of occurring over 10,000 years."

$$10^{-8} \text{ yr}^{-1}$$

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BEHAVIORAL RULES: CONDITIONAL PROBABILITY

1. INDIVIDUAL PROBABILITY VALUES ARE ESTIMATES
   -- LARGE UNCERTAINTY

2. PROBABILITY RANGE IS DEFINED TO BOUND UNCERTAINTY
   -- APPROACH PHYSICAL LIMITS OF VOLCANIC PROCESSES

3. ALTERNATIVE MODELS ARE IMPORTANT IF THEY CHANGE PROBABILITY RANGE
   -- MAY NOT NEED TO DISCRIMINATE ALL MODELS
      (RETIREMENT PROGRAM)

4. PROPAGATION OF CONSERVATIVE OR "WORST CASE" ASSUMPTIONS
   -- PARAMETERS ARE CORRELATED
      OFTEN CAN'T CHANGE ONE WITHOUT EXAMINATION OF OTHERS
   -- CAN LEAD TO PHYSICALLY IMPLAUSIBLE RATES
   -- REALITY CHECK: GEOLOGIC RECORD

5. DATA GATHERING FOR PROBABILITY CALCULATIONS
   -- BURDEN OF PROOF REQUIREMENTS
      EG. CHRONOLOGY STUDIES
   -- PERSPECTIVE OF FALSE POSITIVE/FALSE NEGATIVE
      LW OLD WHEN YOUNG
      LW YOUNG WHEN OLD

6. PROBABILISTIC PERSPECTIVE: COMPARISON OF MODELS
   -- AGREEMENT WITH NRC APPROACH
   -- COMMON GROUNDS FOR COMPARING DIFFERENCES

7. PROFESSIONALISM URGED: PUBLIC SENSITIVITY
   -- CALCULATIONAL DIFFERENCES INSTEAD OF RHETORIC

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E1: Recurrence Rate Models

1. Poisson Model
   - -- cone counts per time
   - -- uniformity of rates
   - -- no event memory
   - -- definition of a volcanic event
   - -- ignores magmatic volume

2. Time-Series Analysis
   - -- insufficient data

3. Volume-Predictable Model
   - -- Cumulative Volume versus Time
   - -- Rate can be Time Dependent
   - -- Supported by the Geologic Record

4. Cluster Model (paleomagnetic results)
   - -- 4 events in 3.7 Ma
   - -- 3 events in Quaternary
   - -- Geometric Control: Clusters

4. Triggered Poisson Process
   - -- Minimum Volume Accumulation to Trigger
   - -- Poisson Process After Exceeding Minimum Volume

Probability Bounds Are Not Sensitive to Recurrence Rate Models

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Recurrence Rates: Bounds From Major Volcanic Fields

Lunar Crater Volcanic Field

82 Quaternary Centers in 28 clusters
> 60 km^3 of magma
vent density: .33

Cima Volcanic Field

29 Quaternary Centers in 22 clusters
> 20 km^3 magma
vent density: .10

Yucca Mountain Region

7 Quaternary Centers in 3 clusters
0.5 km^3 of magma
vent density: .015

Maximum Vent Density

Mauna Kea: .39
Kilimijario: .40

Rate (events/yr)	100,000 yr	1,000,000 yr	2,000,000 yr
10^{-4}	10	100	200
10^{-5}	1	10	20
10^{-6}	-	1	2

Rate Bounds (events/yr)

Lunar 4×10^{-5} to 2×10^{-5}

Cima 2×10^{-5} to 1×10^{-5}

Yucca 10^{-5} to 10^{-6}

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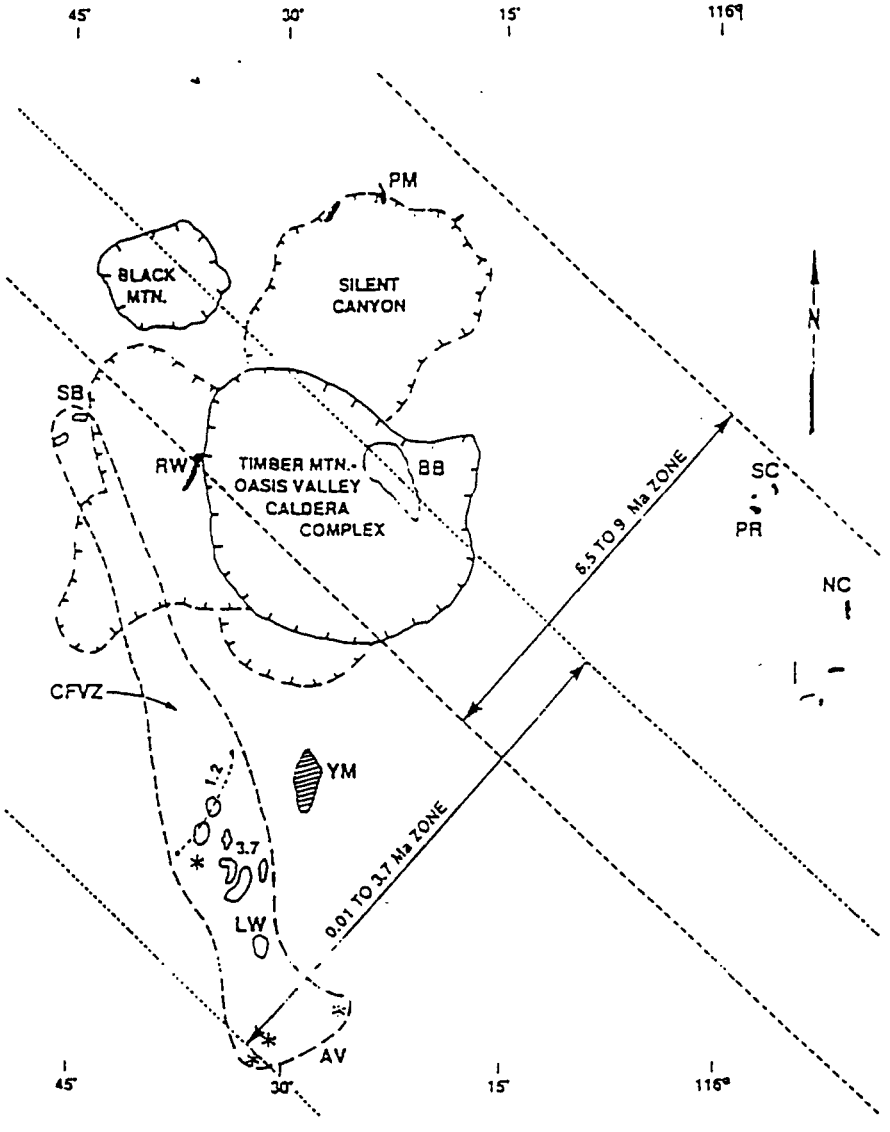
Structural Controls of Volcanism

1. Catch 22
   - -- more events better chance to understand controls
   - -- more events increases E1

2. Yucca Mountain Region
   - -- only 7 events or 4 clusters in 3.7 Ma
   - -- unconstrained structural models may be possible
   - -- NW/NE trends: agreement
   - -- Scale of trends
     - volcanic field
     - volcanic centers

3. Patterns of Major Basaltic Volcanic Fields
   - -- relatively sharp boundaries
   - -- distinct patterns within fields
   - -- dispersion: km versus 10's of kms

PLIOCENE - QUATERNARY BASALT DISTRIBUTION
YUCCA MOUNTAIN REGION



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Yucca Mountain Region: Structural Model
(despite cautions)

1. Upper Mantle: Great Basin and Basin and Range
   -- partial melt

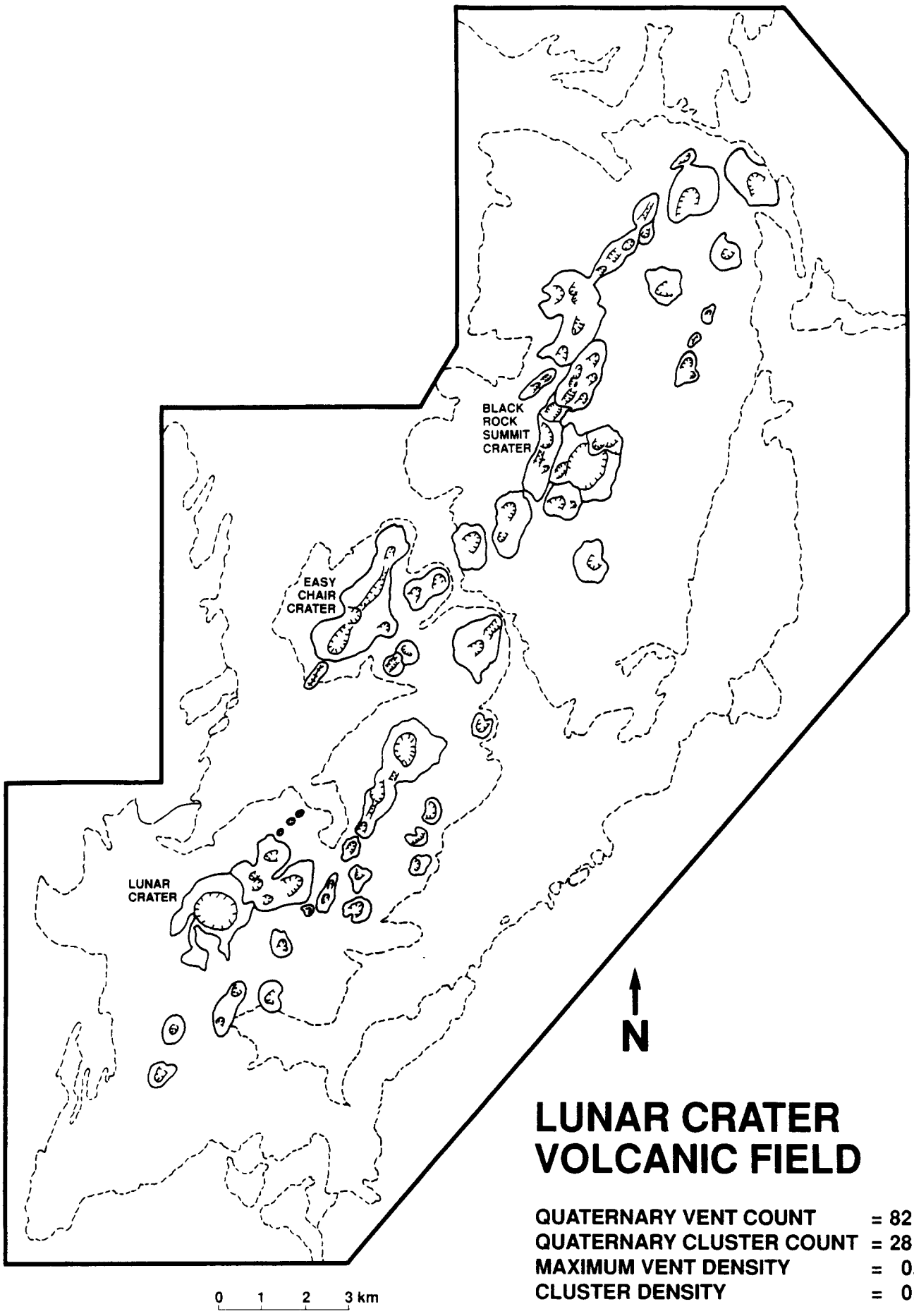
2. Basalt Generally Trapped in the Crust
   -- geophysics

3. Ascent Through Crust (struggle)
   -- aided in areas of higher extensional rates
   -- magmas probably explore paths of least resistance
   -- random aspect to ascent process

4. N-W Trending Mantle Zone
   -- residual Walker Lane structure?

5. Random Model, 1982 Paper: 10^{-3} to 10^{-4}
   -- EPRI models of volcanic fields
   -- Smith et al. model

INSIGHTS: MAJOR VOLCANIC FIELDS

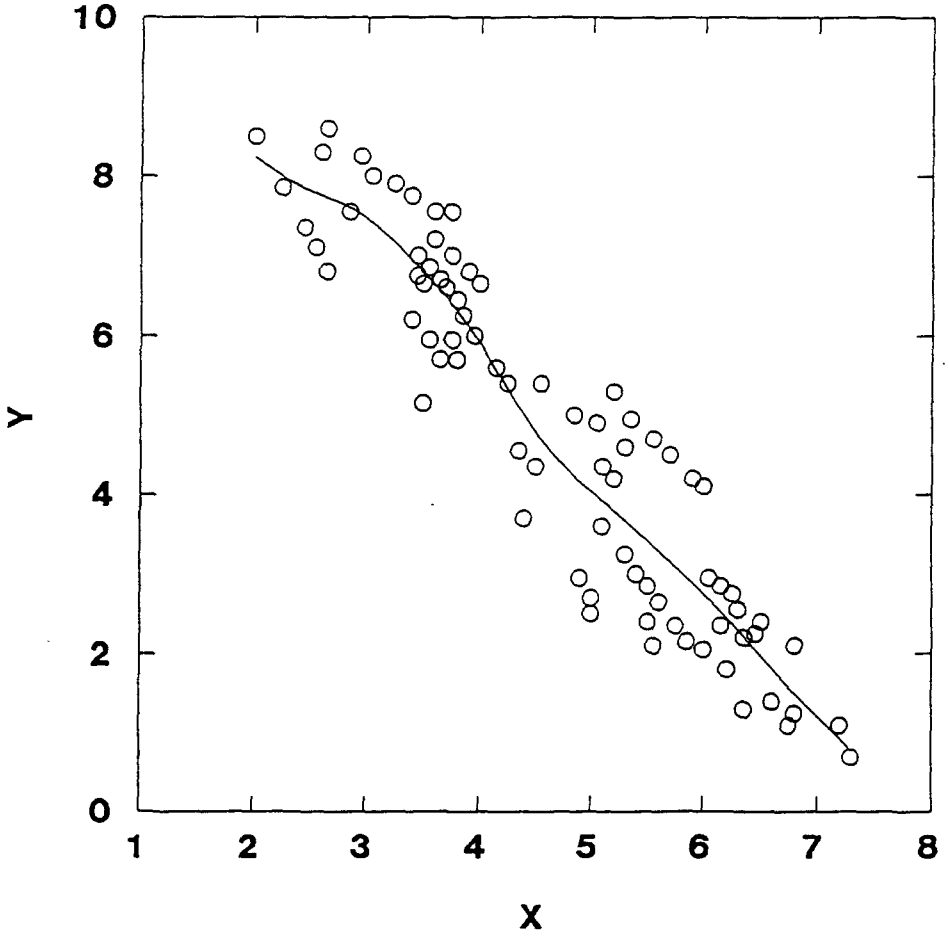


LUNAR CRATER VOLCANIC FIELD

QUATERNARY VENT COUNT	= 82
QUATERNARY CLUSTER COUNT	= 28
MAXIMUM VENT DENSITY	= 0.3
CLUSTER DENSITY	= 0.12

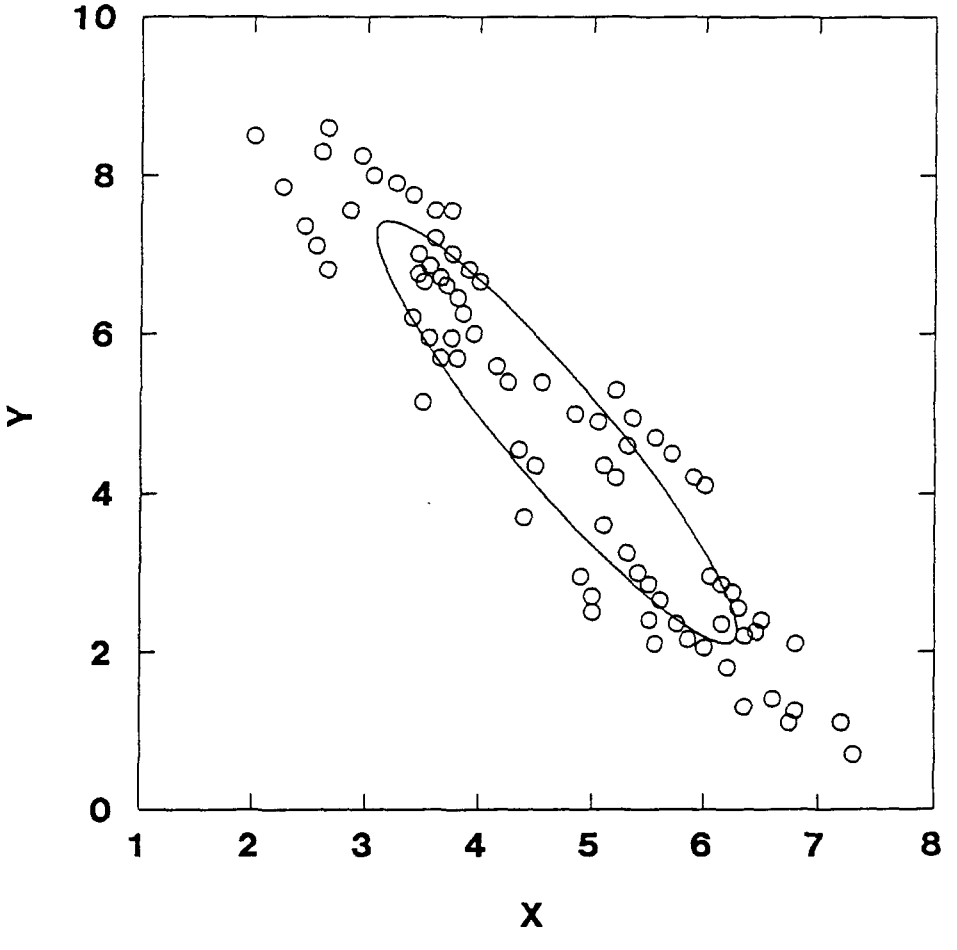
LUNAR VOLCANIC FIELD

distance weighted least squares



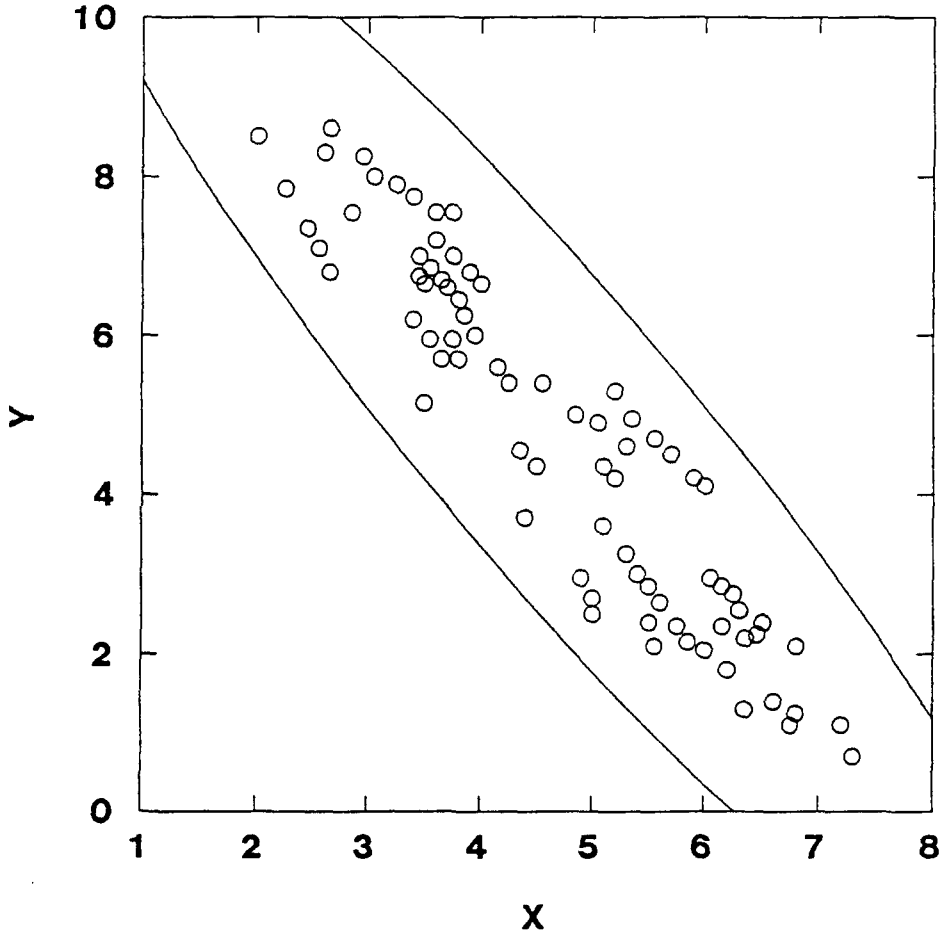
LUNAR VOLCANIC FIELD

gaussian bivariate ellipsoid: CF=50

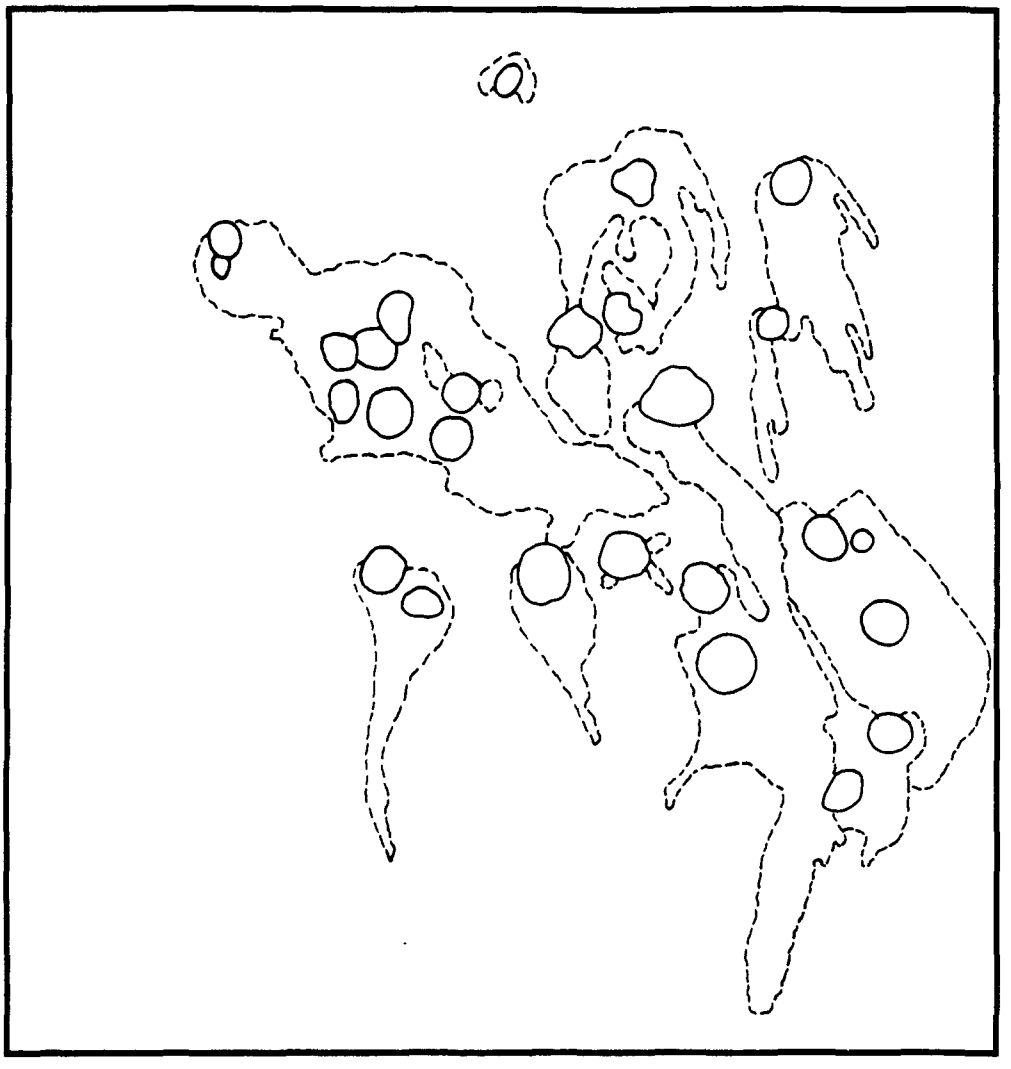


LUNAR VOLCANIC FIELD

gaussian bivariate ellipsoid: CF=.99



CIMA VOLCANIC FIELD, CALIFORNIA



0 1 2 3 4 km

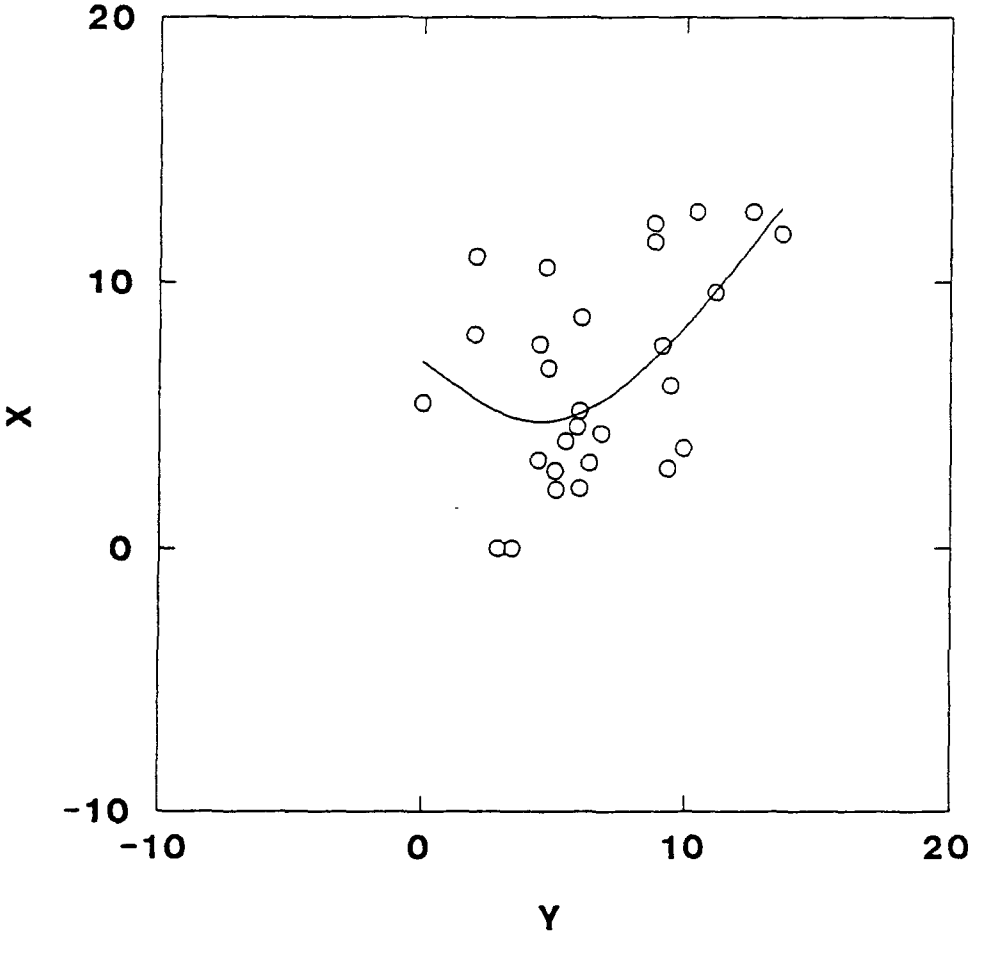
N

MAXIMUM VENT DENSITY = 0.14 km^2

QUATERNARY RECURRENCE RATE = 1.6 x 10^{-5} EVENTS YR^{-1}

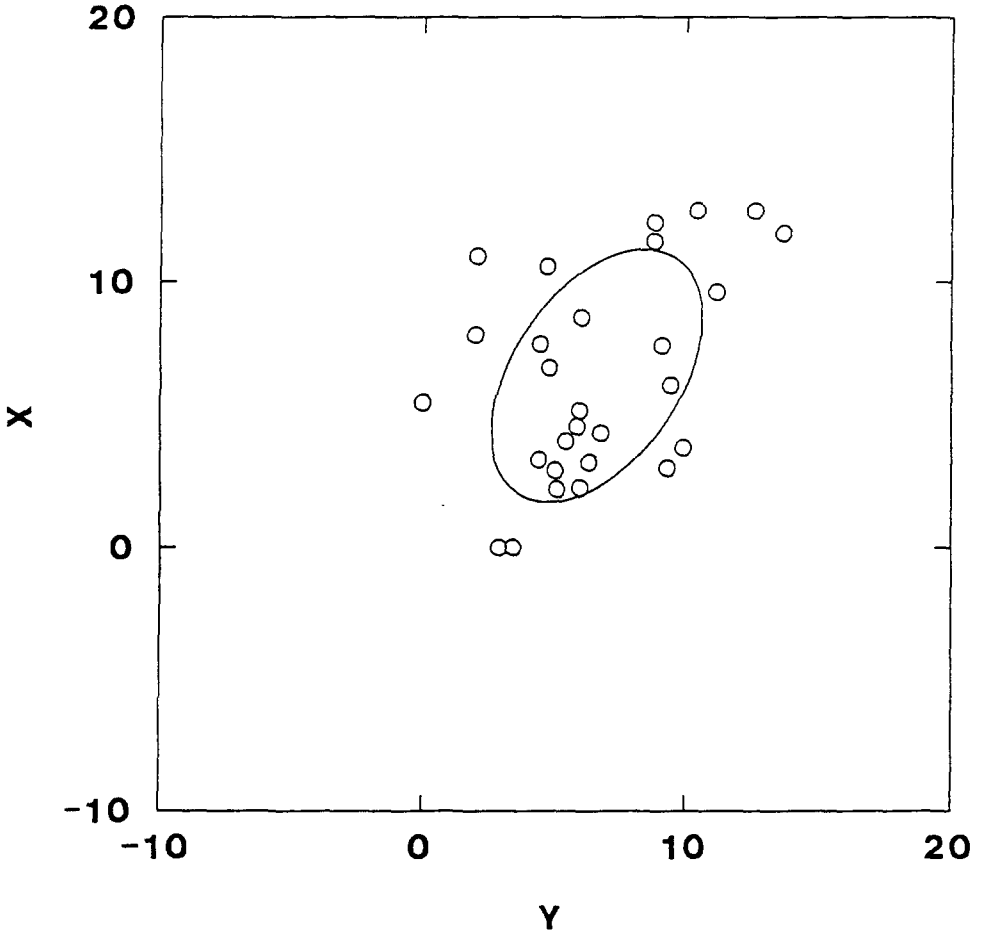
CIMA VOLCANIC FIELD

distance weighted least squares



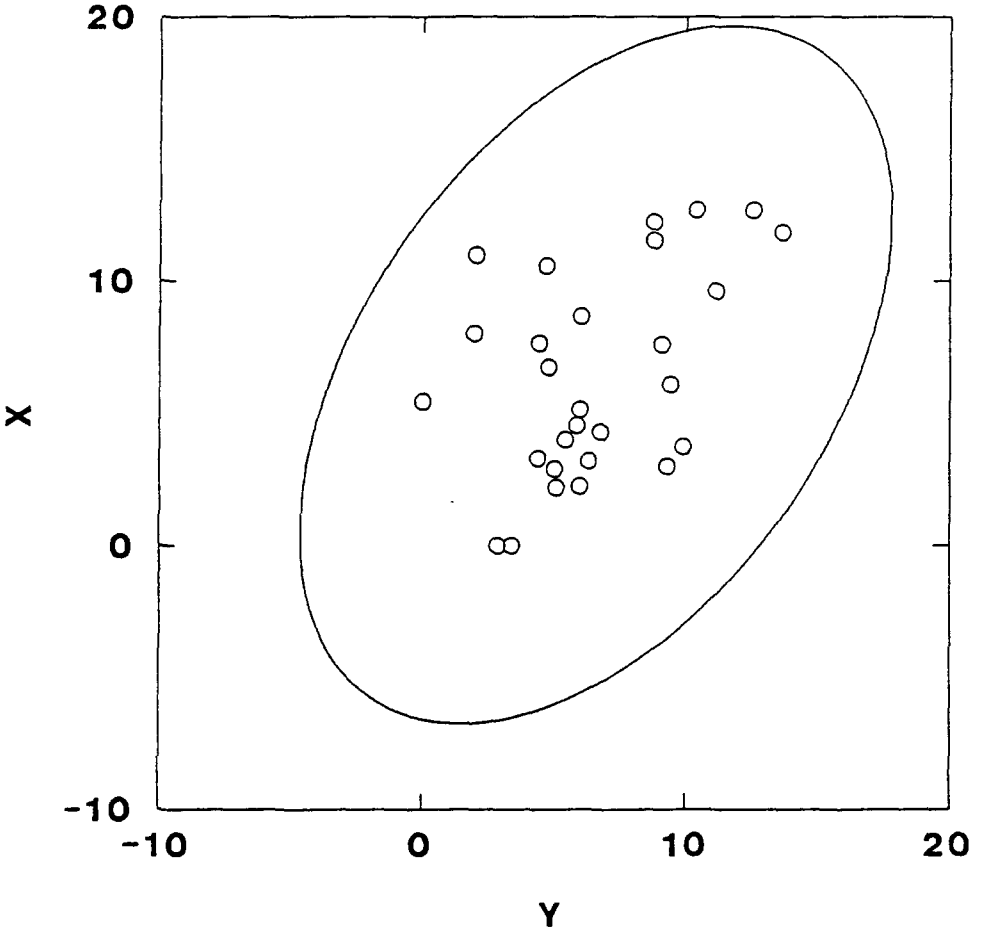
CIMA VOLCANIC FIELD

gaussian bivariate ellipsoid, CF=.50



CIMA VOLCANIC FIELD

gaussian bivariate ellipsoid, CF=.99



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Recurrence Rate (E1): Assume Steady State System

Volcanism Appears to be Waning

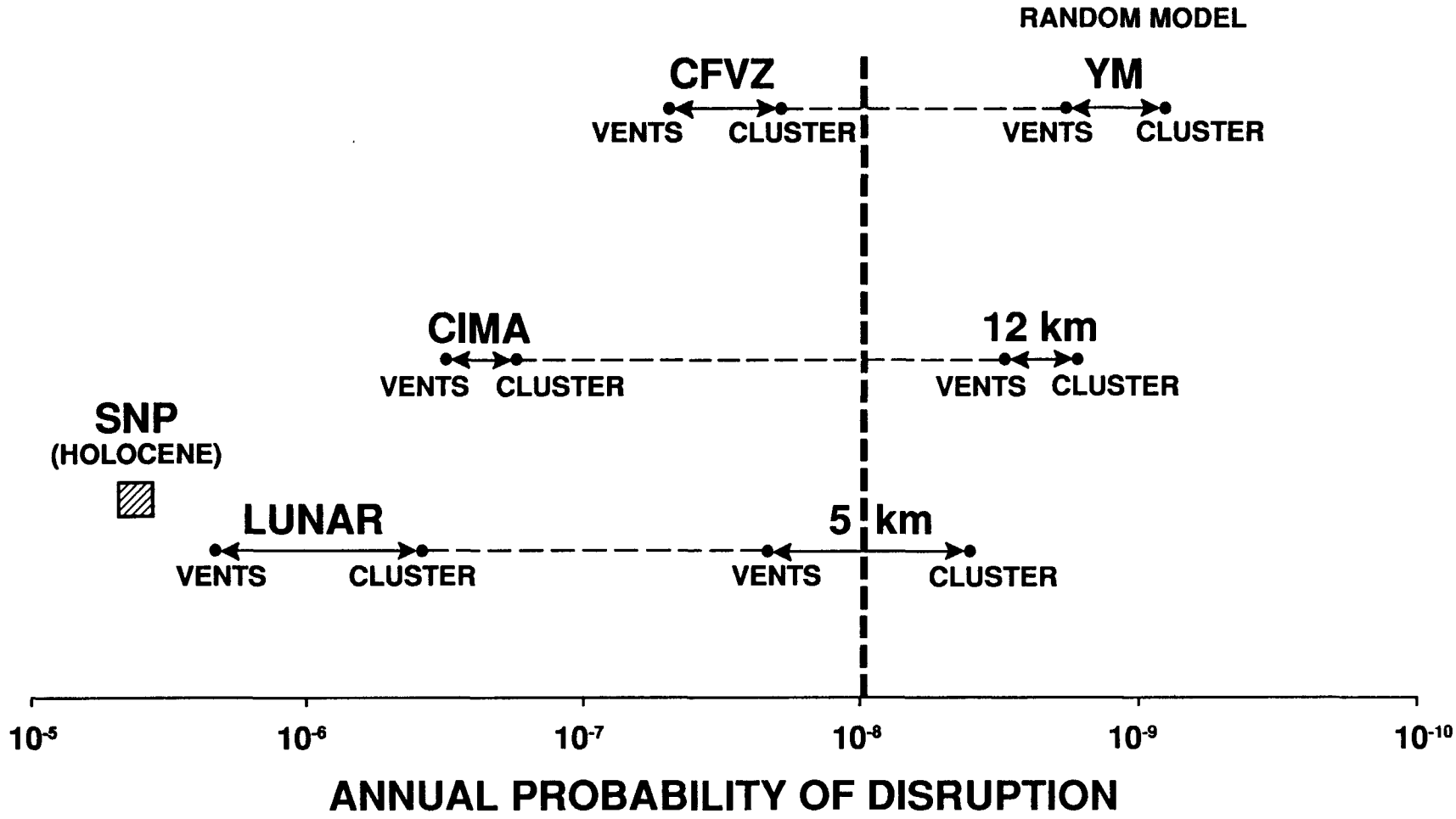
- -- Decreasing volume through time (3.7 Ma to Holocene)
- -- Decreasing magma effusion rates (lava morphology)
- -- Geochemical trends/analogues
- -- Duration of continental basaltic volcanic fields

Disruption Ratio (E2): Calculation Conservative

Volcanic Event Unlikely at Yucca Mountain

- -- Pass patterns of activity: NW zone
- -- Basalt eruptions rare in range interiors
- -- Geometry of basaltic volcanic fields

QUATERNARY VENT COUNTS



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