Methods Developed by the U.S. Nuclear Regulatory Commission to Evaluate Risk from Fault Displacements Through a Potential Waste Repository, Yucca Mountain, Nevada, U.S.A.

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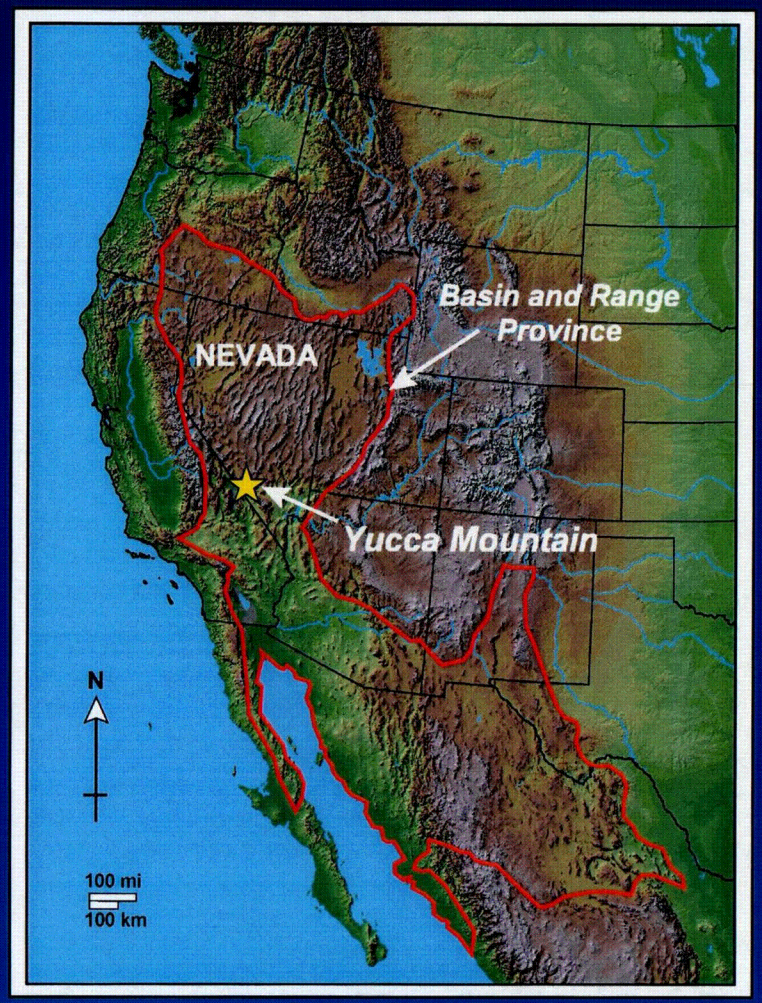
OUTLINE

- INTRODUCTION
- BACKGROUND/GEOLOGY/FAULTING
- METHODOLOGY I
  - Total-system Performance Assessment Code (TPA)
  - Faulto Module
- METHODOLOGY II
  - Historic Basin and Range Earthquake Analog
- SUMMARY

INTRODUCTION - Background



- North American Basin and Range Province
  - Tectonically active since the Cenozoic (65 Ma)
  - Characterized by complex interactions of strike-slip and extensional deformation

Base Map from USGS Eros Data Center, 1999

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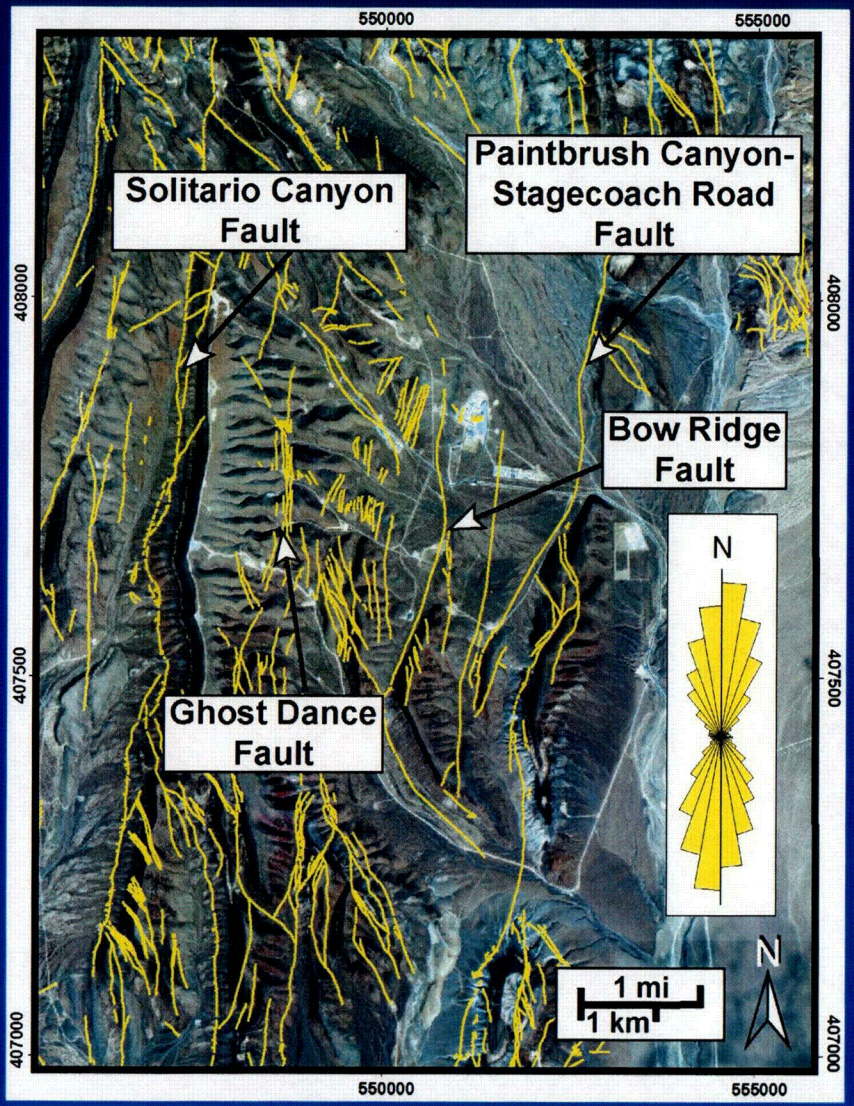
FAULTS AT YUCCA MOUNTAIN



- Contemporaneous Faulting
  - Elongated Ridges Bounded by N-Trending Normal Faults
  - Ridges Crossed by NW-Trending Oblique-Slip to Dextral Strike-Slip Faults
- Tectonically Active
  - Quaternary faulting
  - Historic seismicity
  - Recorded strain accumulation

Fault Coverage from Simonds et al., (1995)

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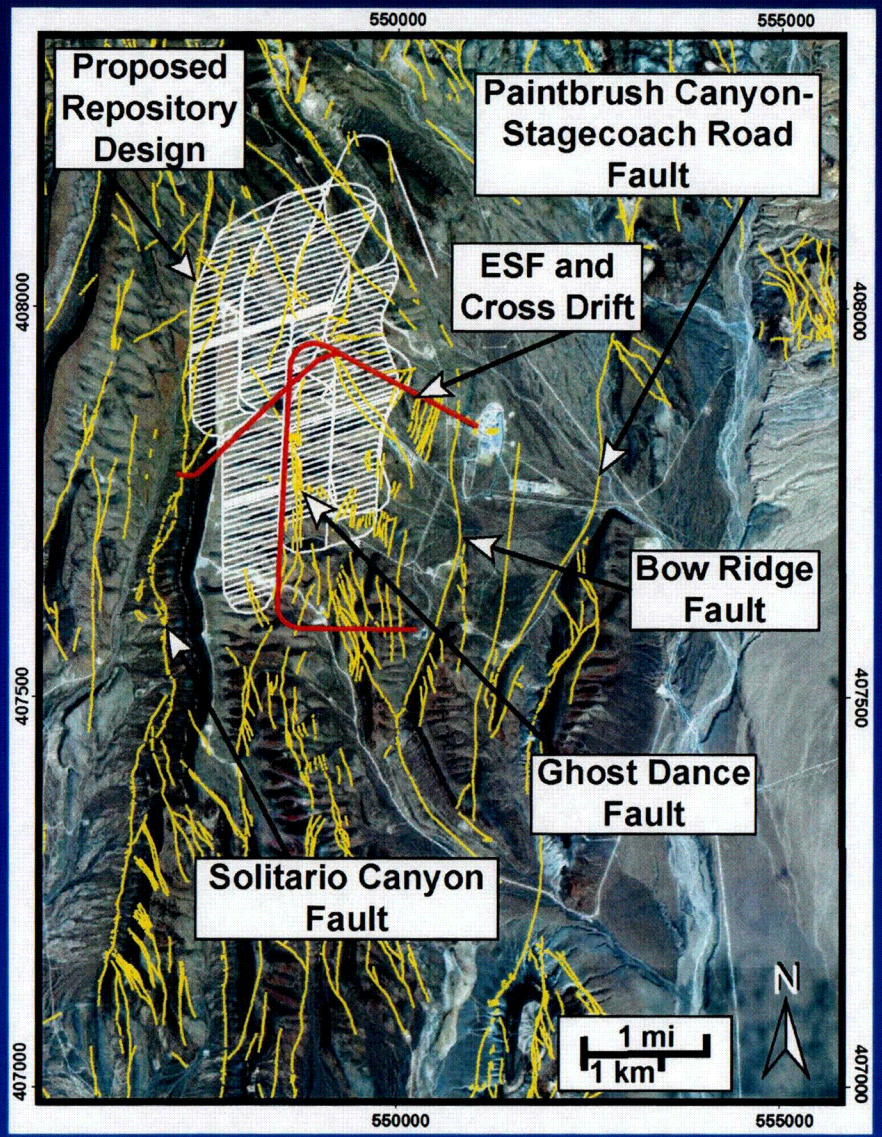
EVALUATION OF FAULTING HAZARD



- DOE Conducted Probabilistic Fault Displacement Hazard Assessment
- DOE developed fault displacement hazard curves
  - Principal Faults (e.g., Solitario Canyon Fault)
  - Secondary Faults (e.g., Ghost Dance Fault)

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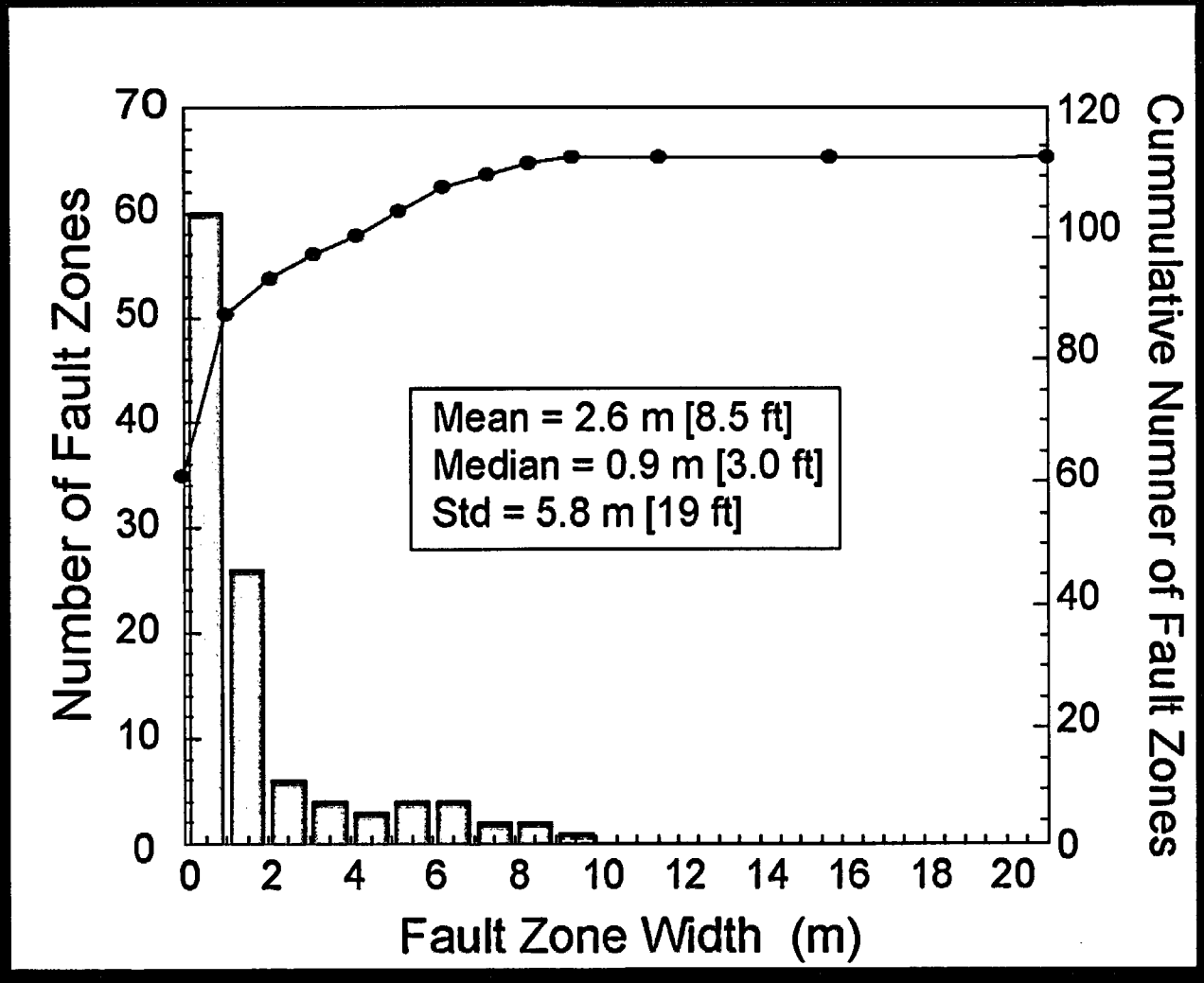
METHODOLOGY I - Important Considerations

- Evaluate Both Principal and Secondary Faults
- Abstract Important Fault Characteristics in TPA code
  - Orientation of fault relative to engineered drifts
  - Fault width
  - Timing of faulting event
  - Threshold displacement that could lead to damage of engineered systems (e.g., waste packages)
  - Probability of that threshold displacement

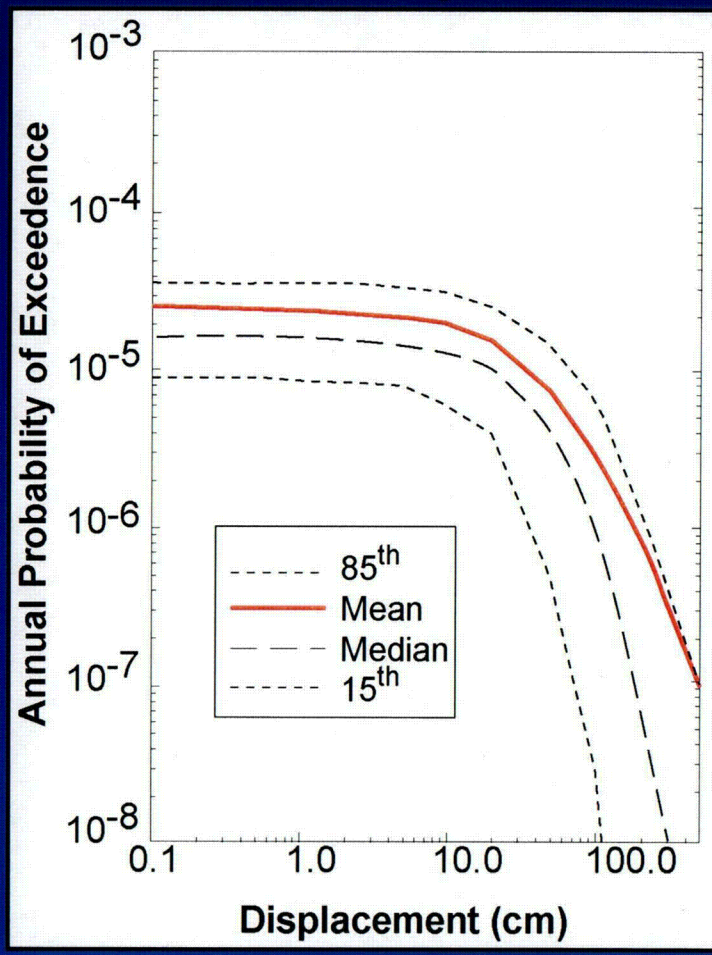
METHODOLOGY I - Fault Zone Width (FZW)



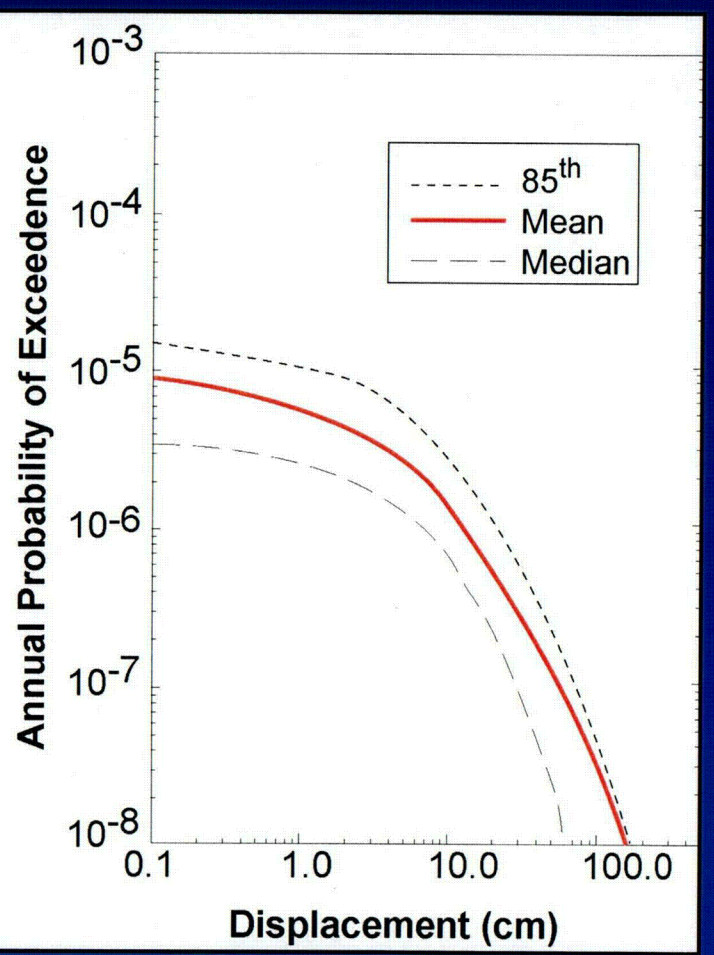
- Develop probability distribution functions (PDF) of fault width based on data from Bureau of Reclamation's mapped fault surfaces in Yucca Mountain

METHODOLOGY I - Probability

Solitario Canyon Fault



Ghost Dance Fault



From CRWMS M&O, (1998)

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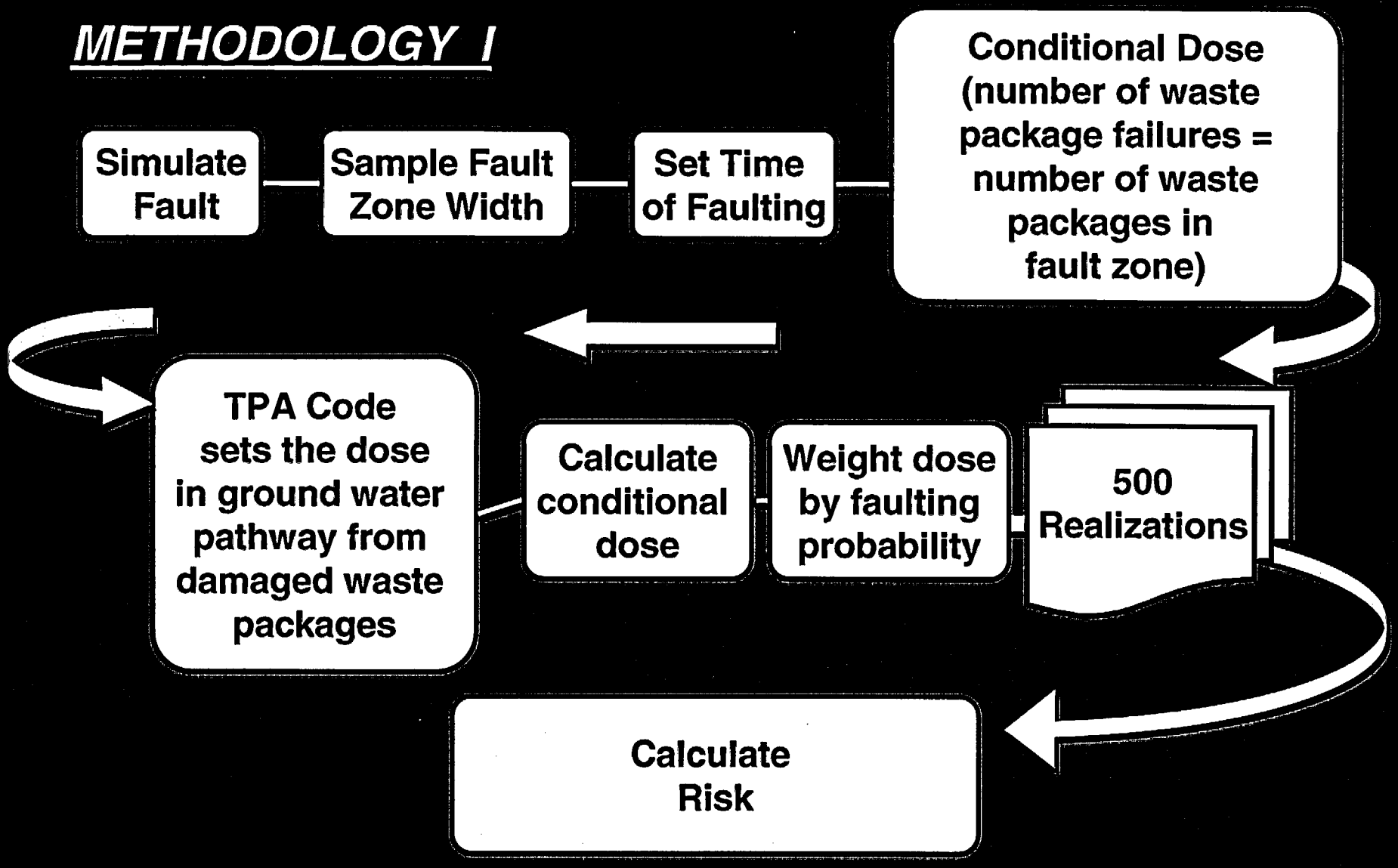
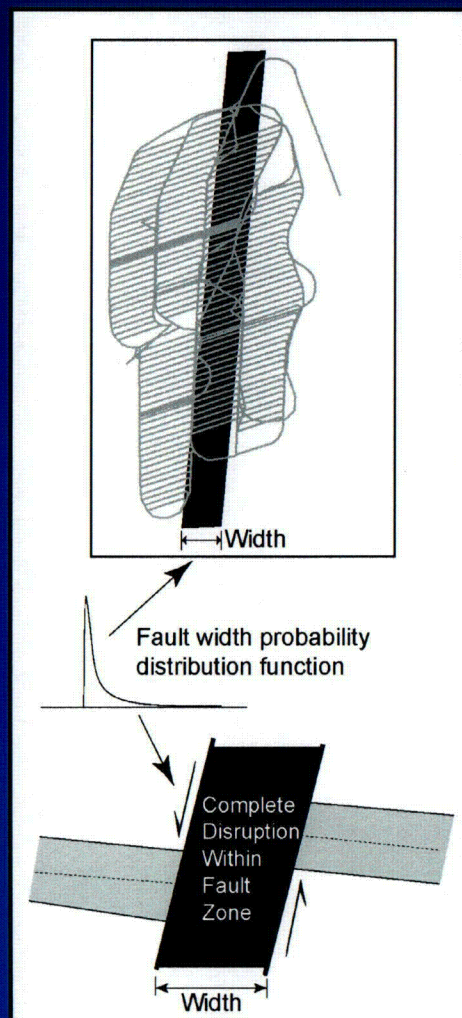
METHODOLOGY I

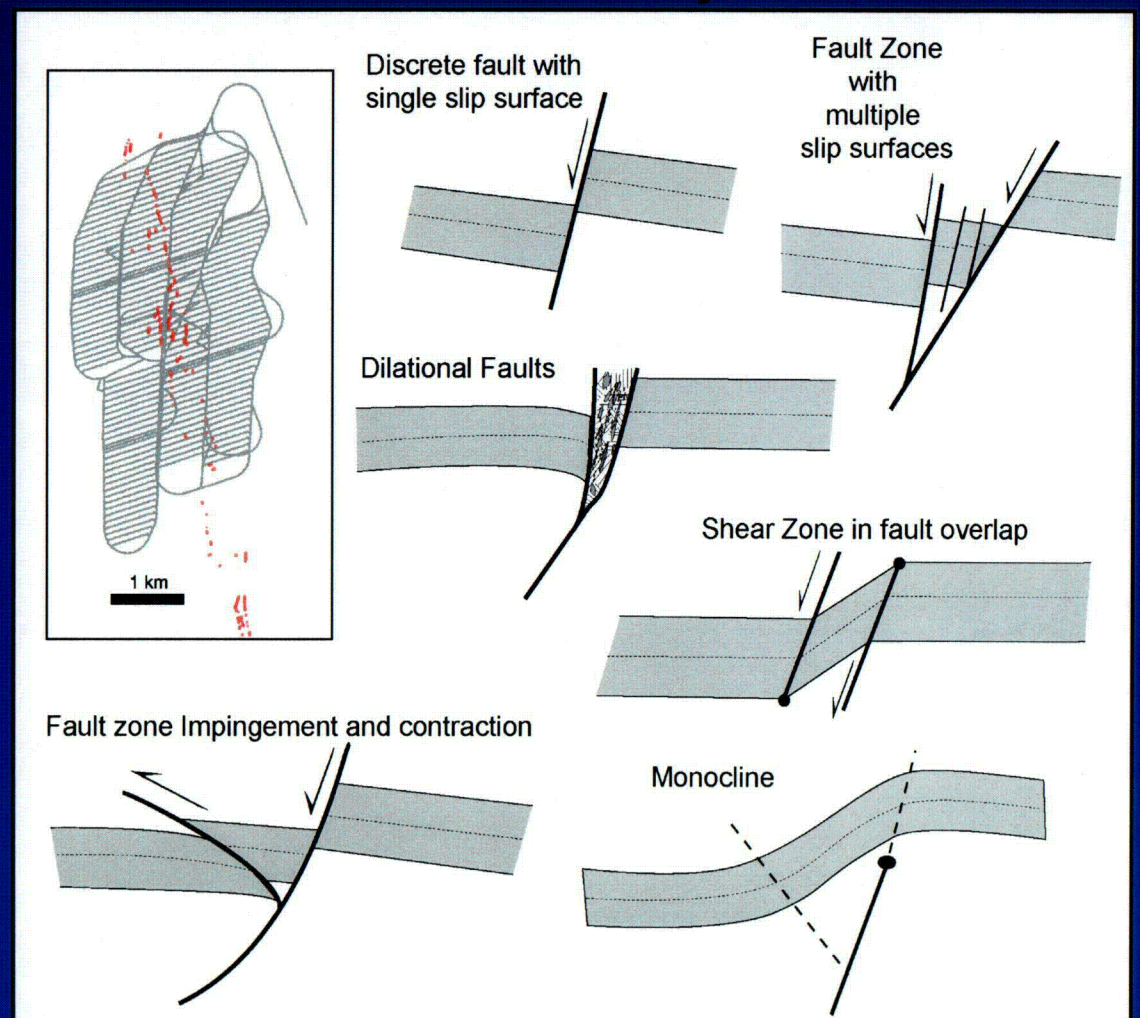


METHODOLOGY I - Limitations

FAULTO Module



Natural Fault Systems



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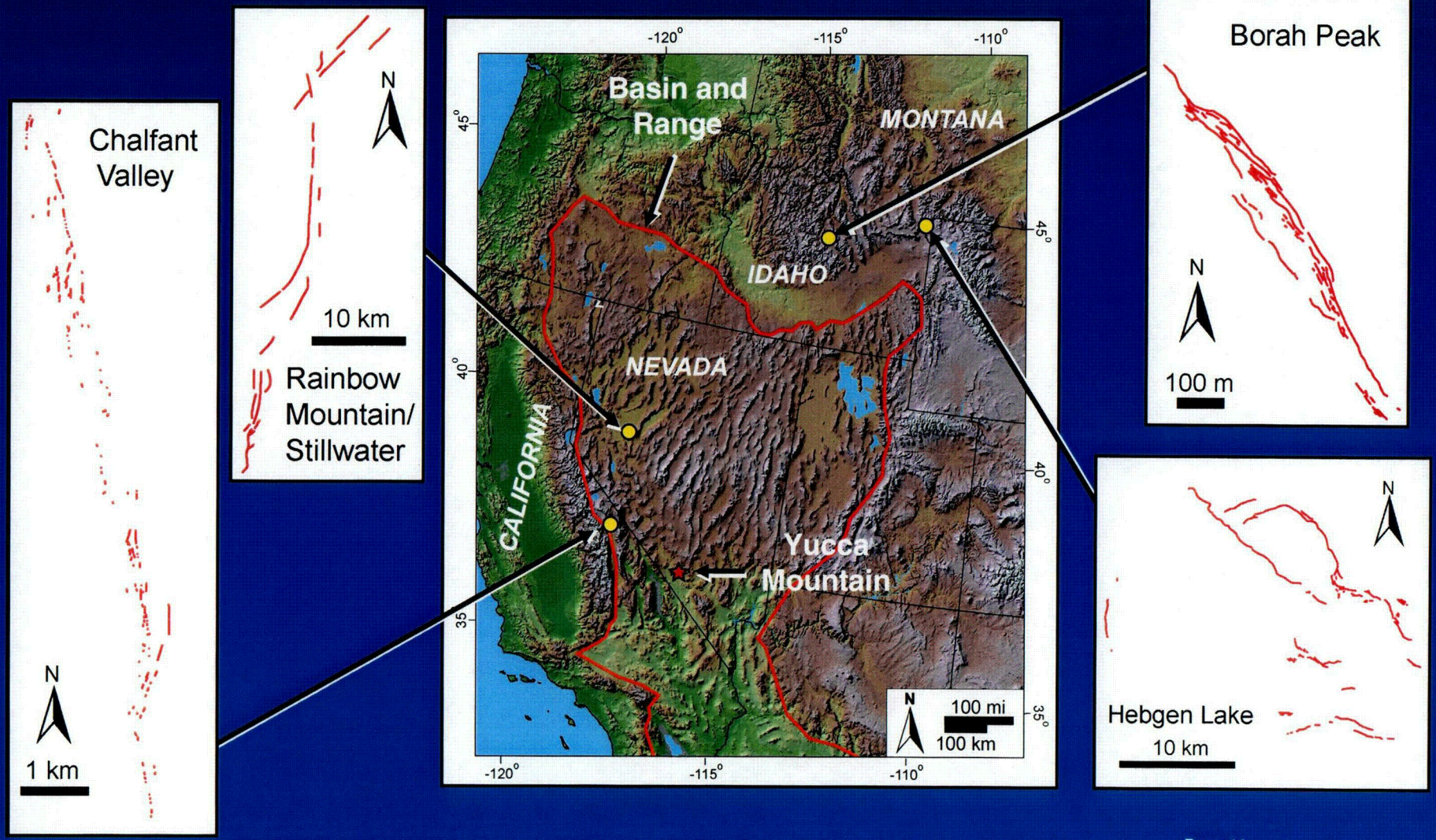
METHODOLOGY II - Analog
Faulting in the Basin and Range



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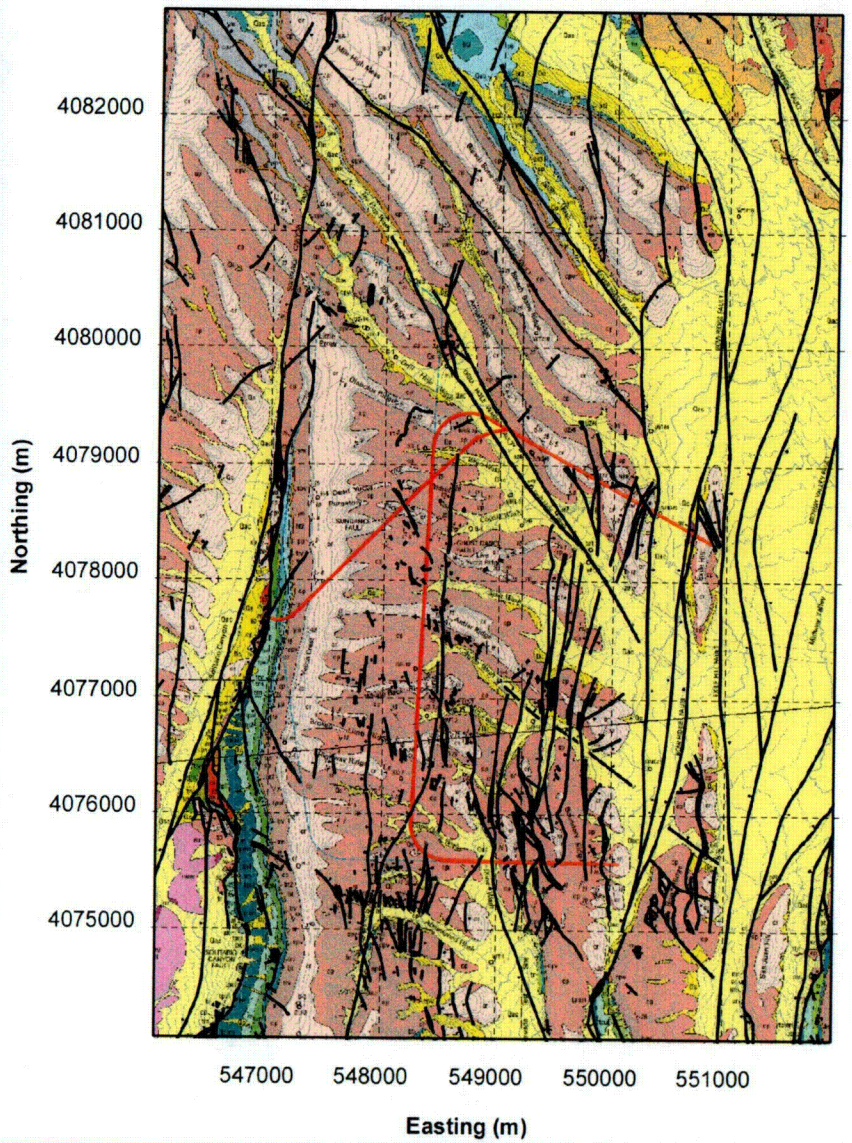
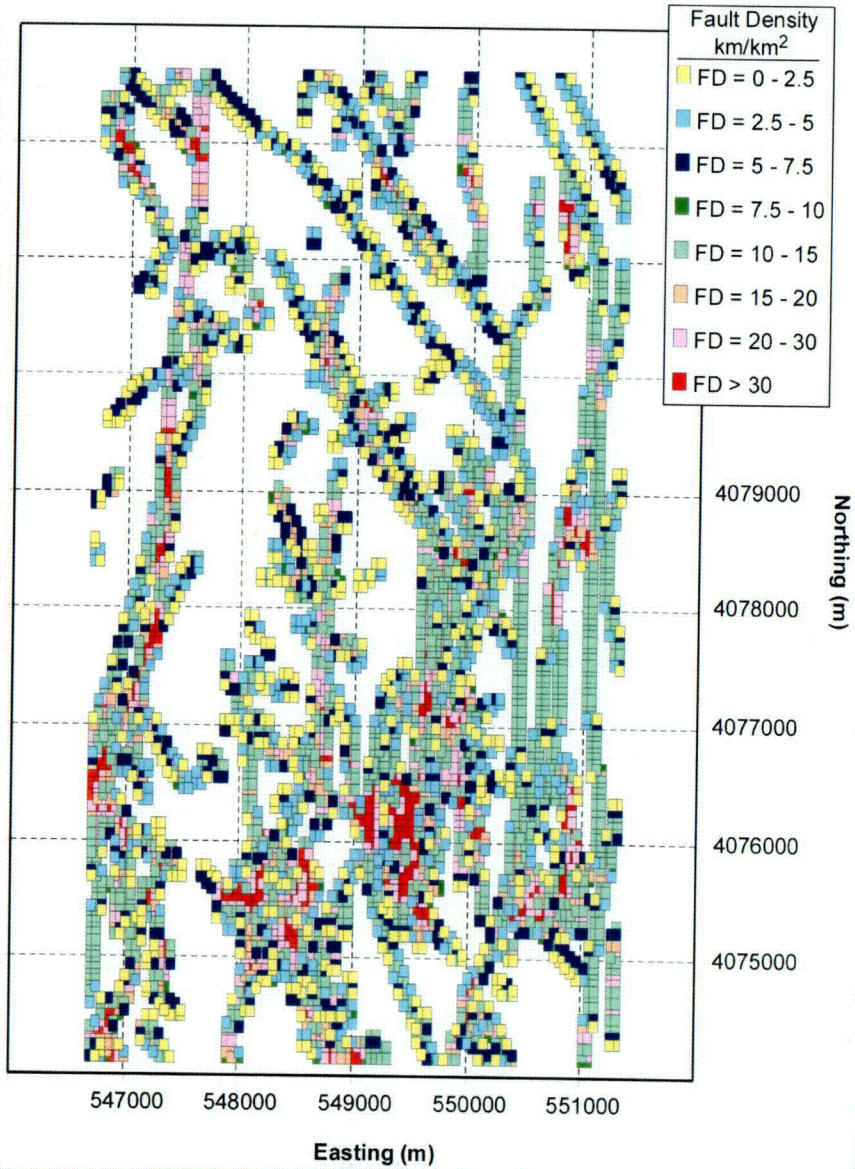
Yucca Mountain Fault Density Map





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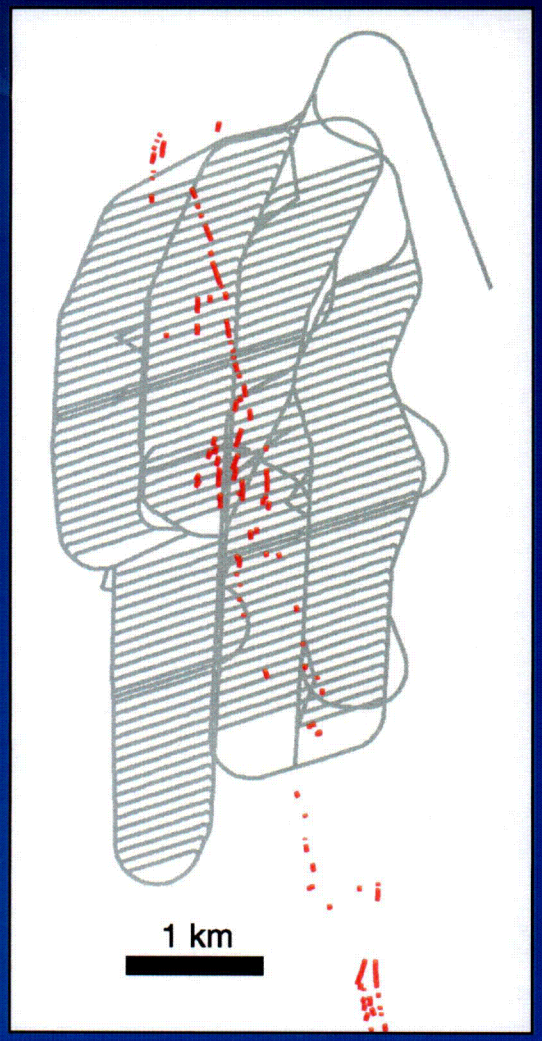
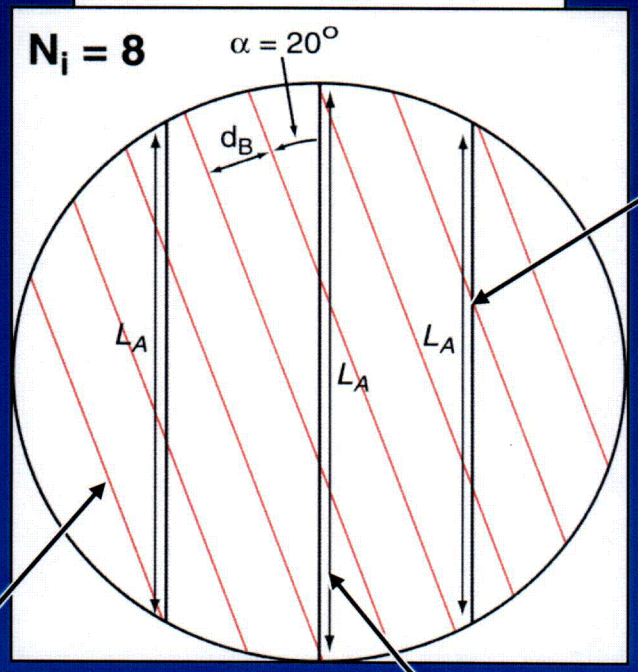
METHODOLOGY II - Drift Intersection Analysis



$$N_i \approx round\{\frac{\sin\alpha}{d_B}(\sum L_A)\}$$

N_i = Number of Intersections



Intersection

d_B = Drift Density

L_A = Rupture Trace Length

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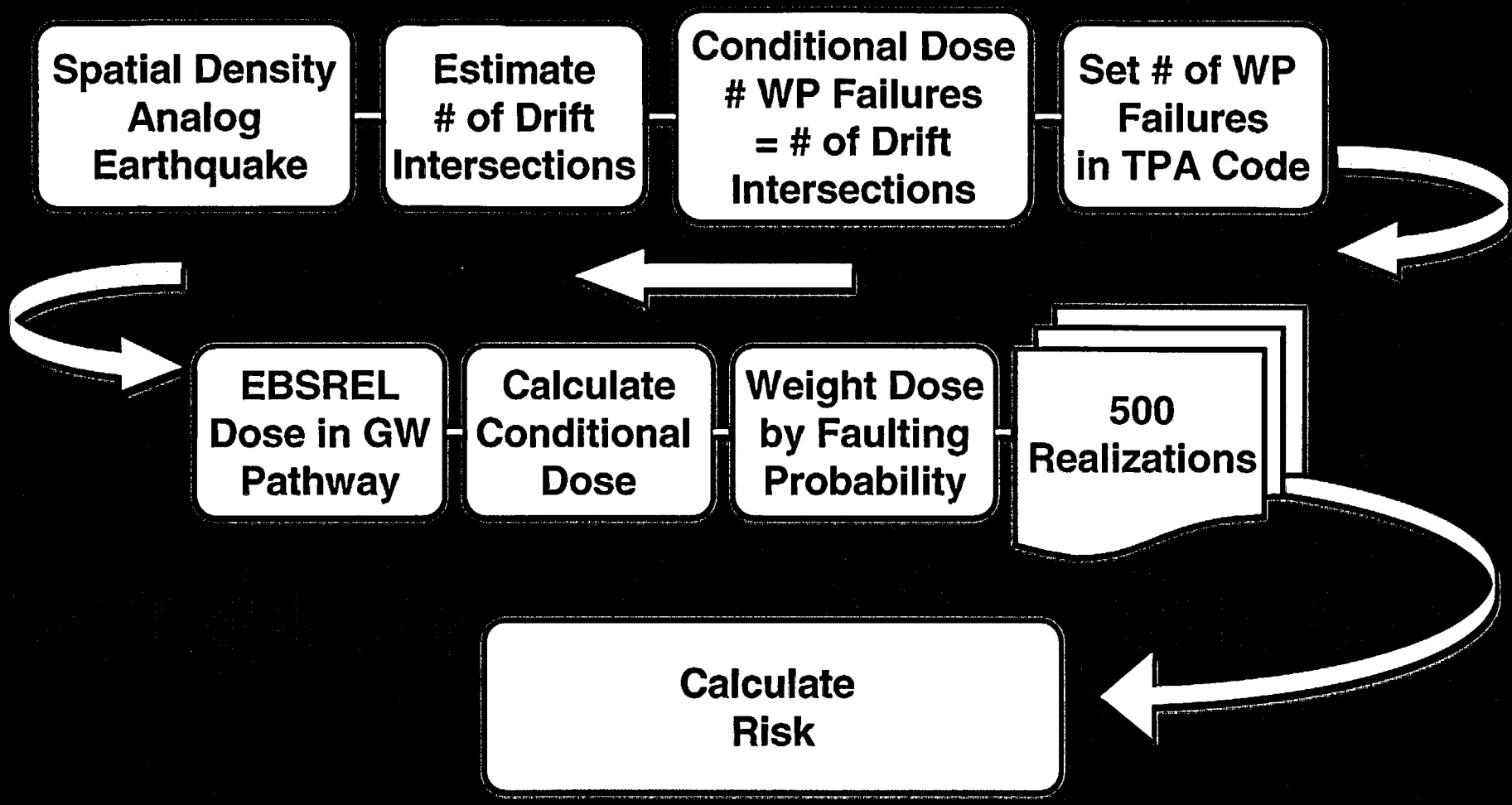
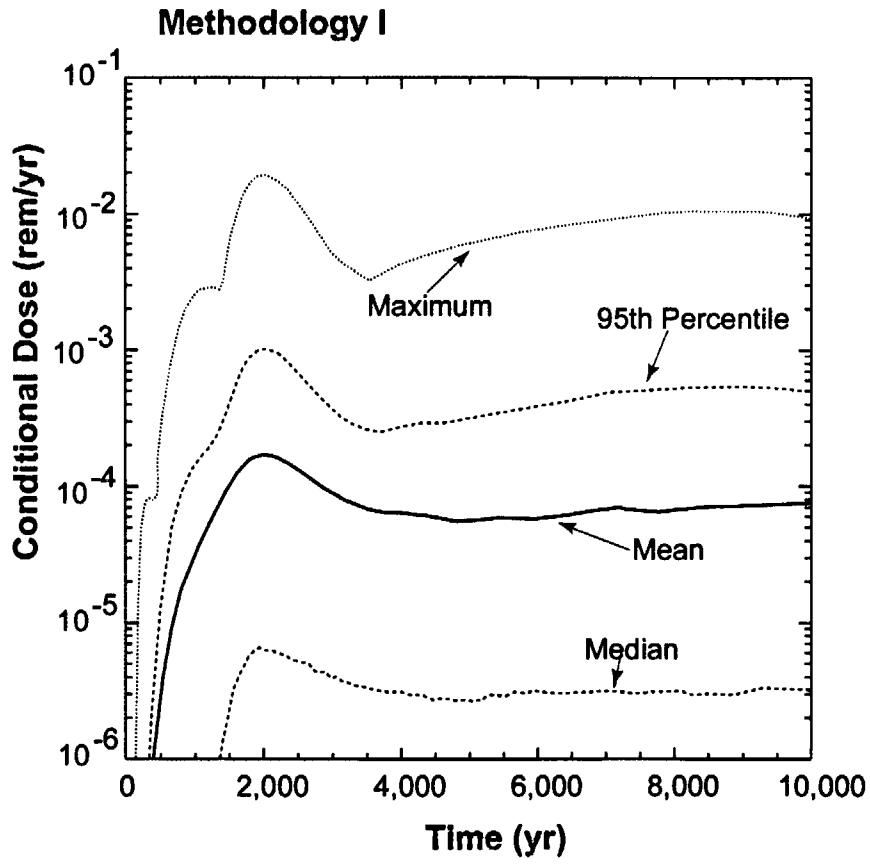
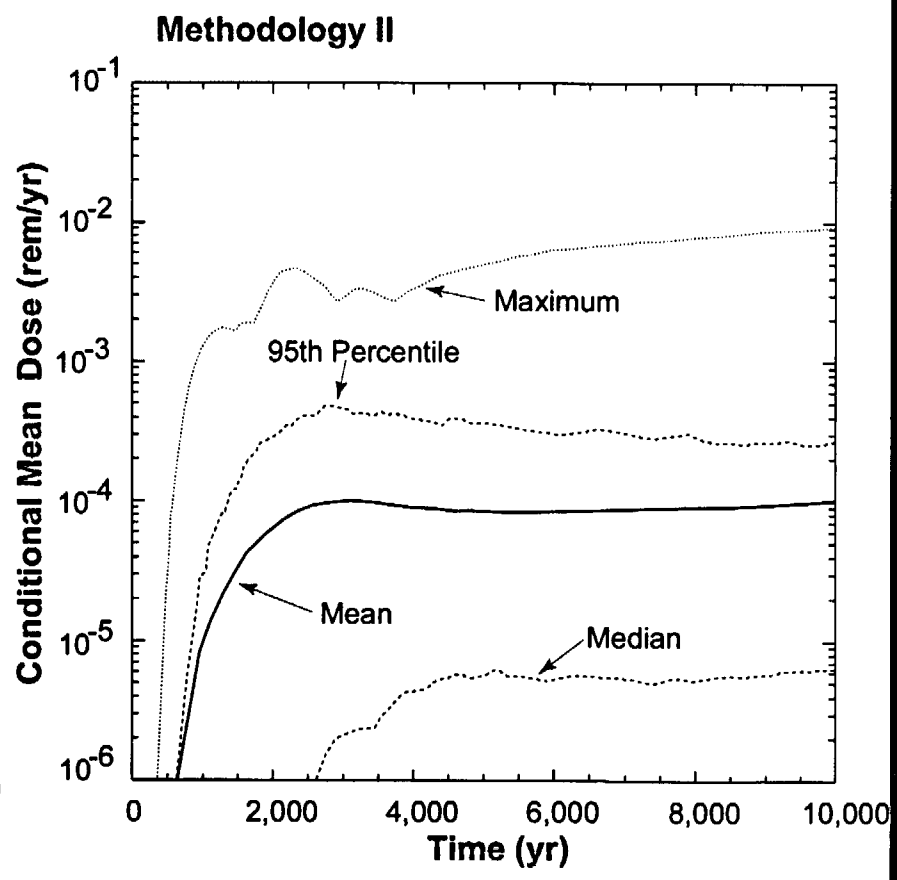
METHODOLOGY II



Example Results





SUMMARY

- Two Methodologies have been developed to evaluate faulting and associated risk during the post-closure period (10,000 years)

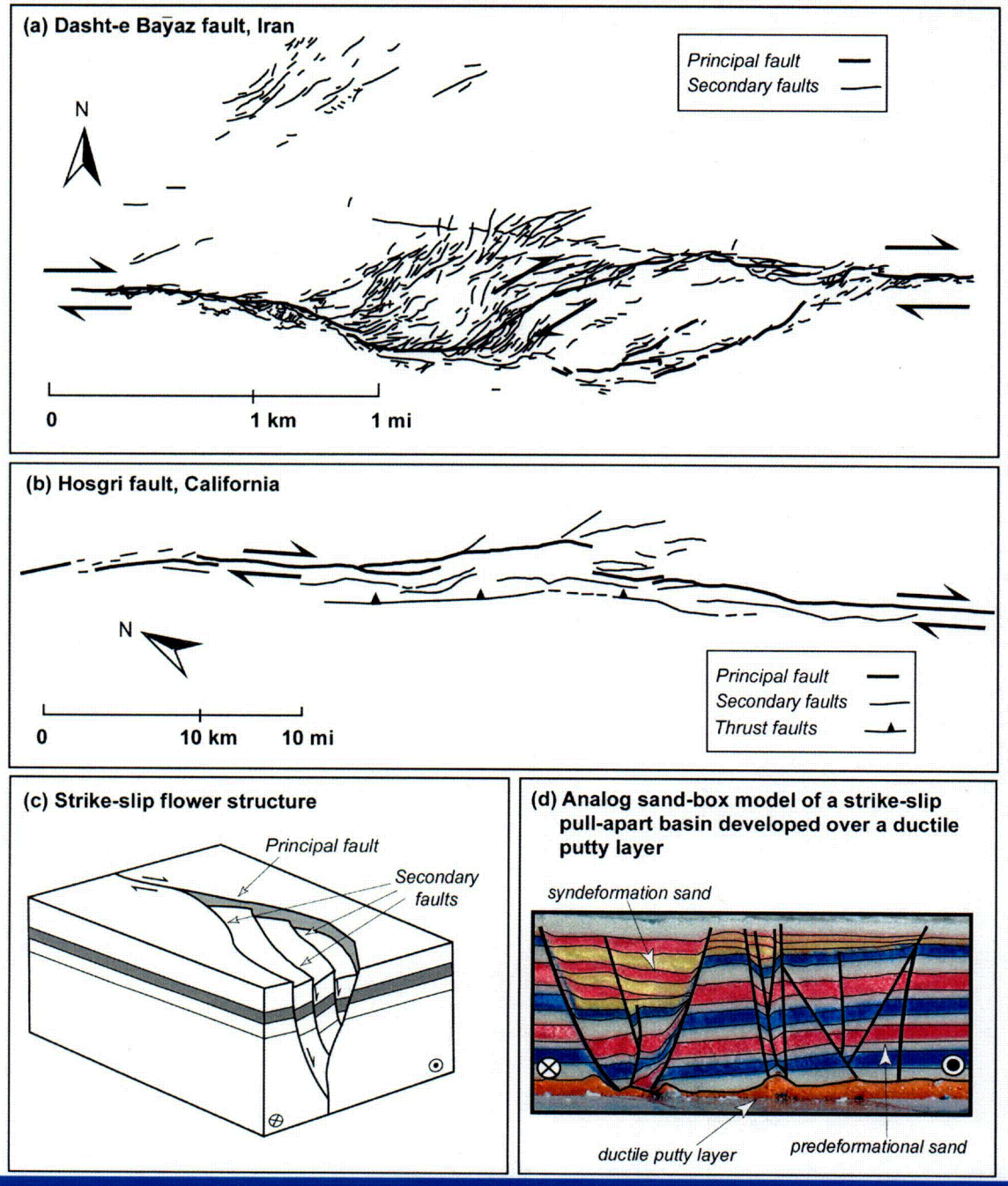
- Methodology I (TPA/FAULTO Module)
  - Simulates single fault rupture within repository and calculates resulting number of waste packages intersected within the fault zone

  - Conditional analyses (faulting is forced to occur) and risk (if any) is estimated by weighing the waste package failures or dose by the DOE probabilistic fault displacement hazard results

SUMMARY

- Methodology II
  - Evaluates distributed faulting by considering faulting patterns from historic earthquakes in the Basin and Range Province
  - Estimates the number of intersected waste packages using fault rupture densities and repository drift spacing and orientation
  - Results weighted by probability of historical faulting event with similar displacements
- Both methodologies indicate risk from faulting is small

BACK UP SLIDES



Issue: Must consider both principal and secondary faults like those associated with strike-slip faulting

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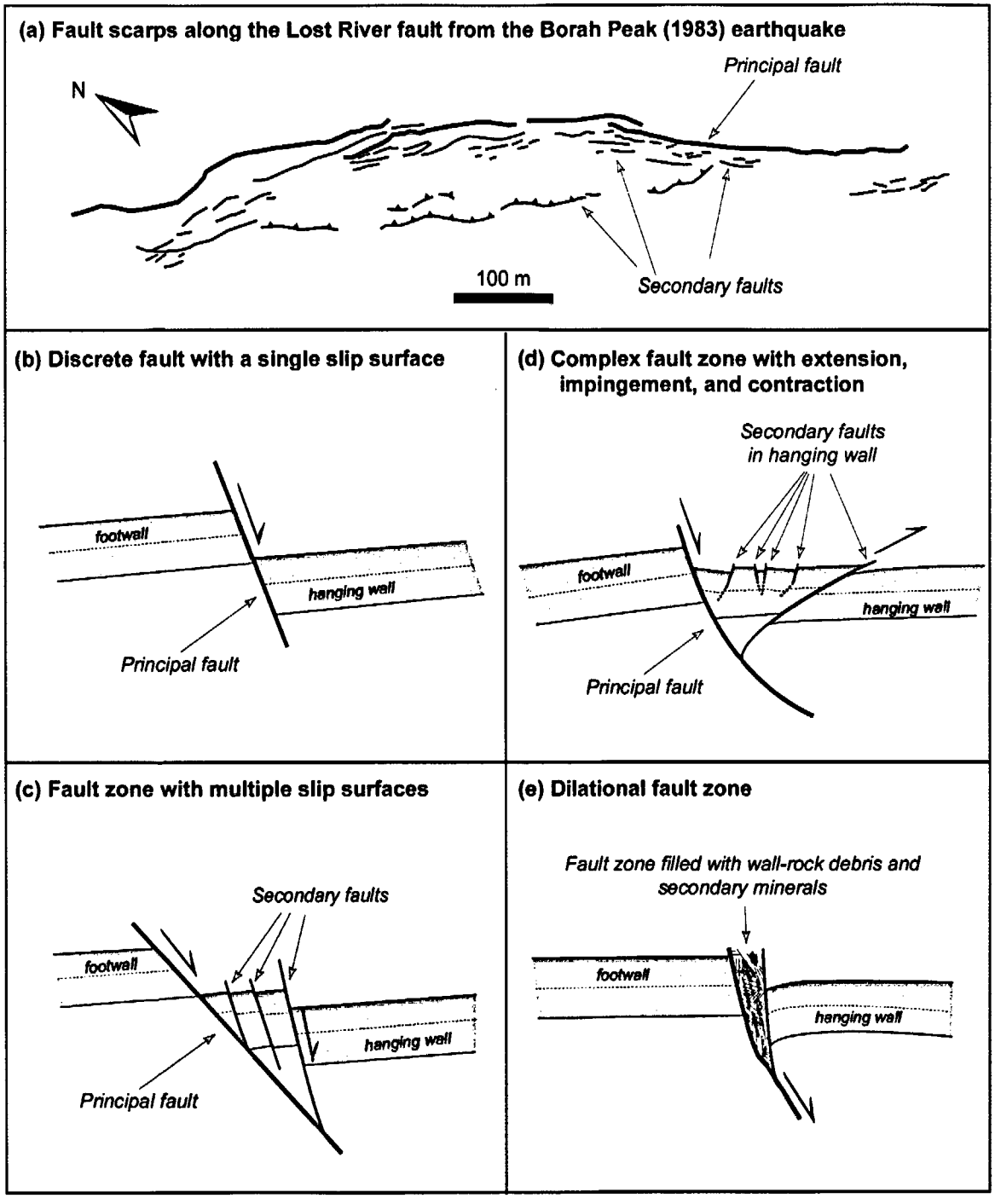
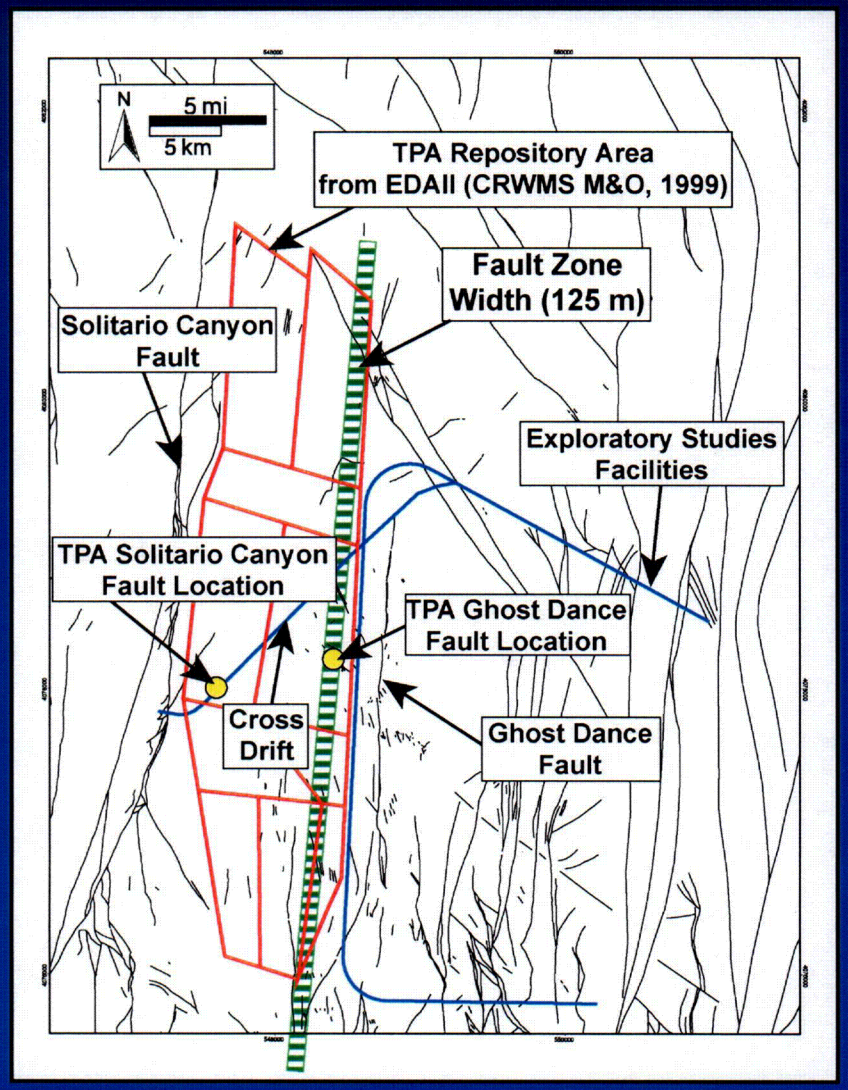


or principal and secondary faults associated with dip-slip faulting

METHODOLOGY I - PDFs



– PDFs - select characteristics for faulting event

Fault Coverage from Day et al., (1998)

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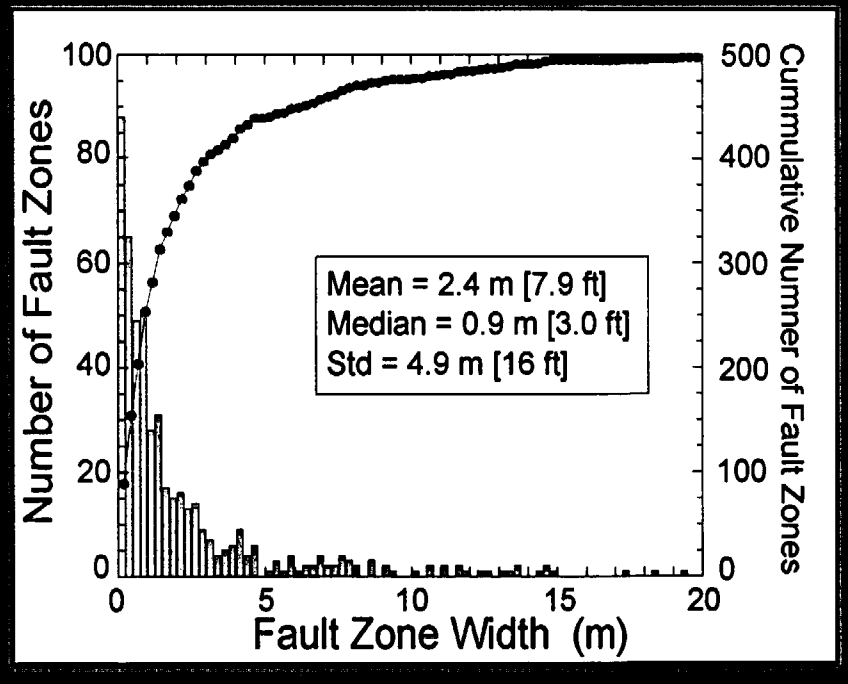
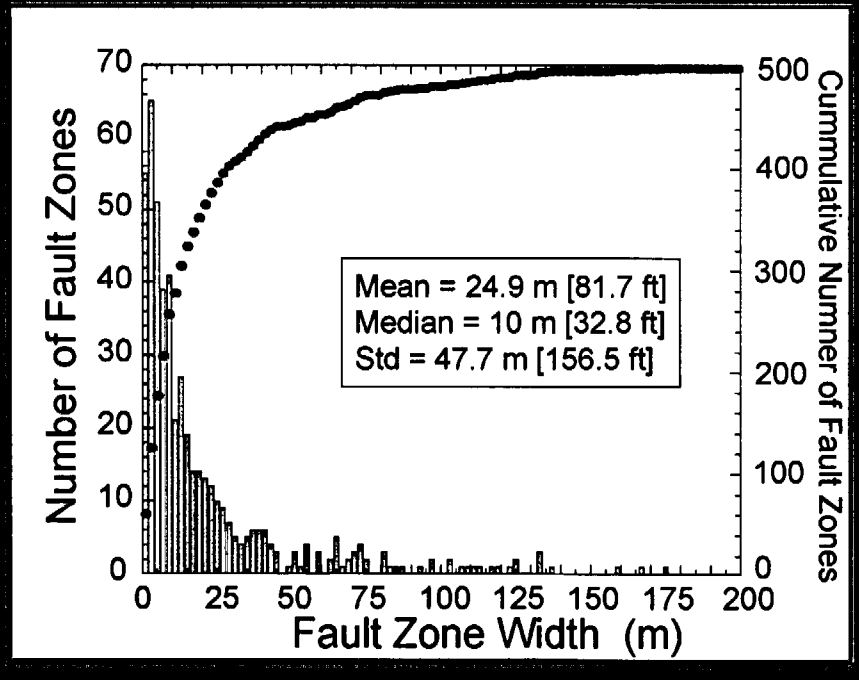
METHODOLOGY I

Ghost Dance Fault

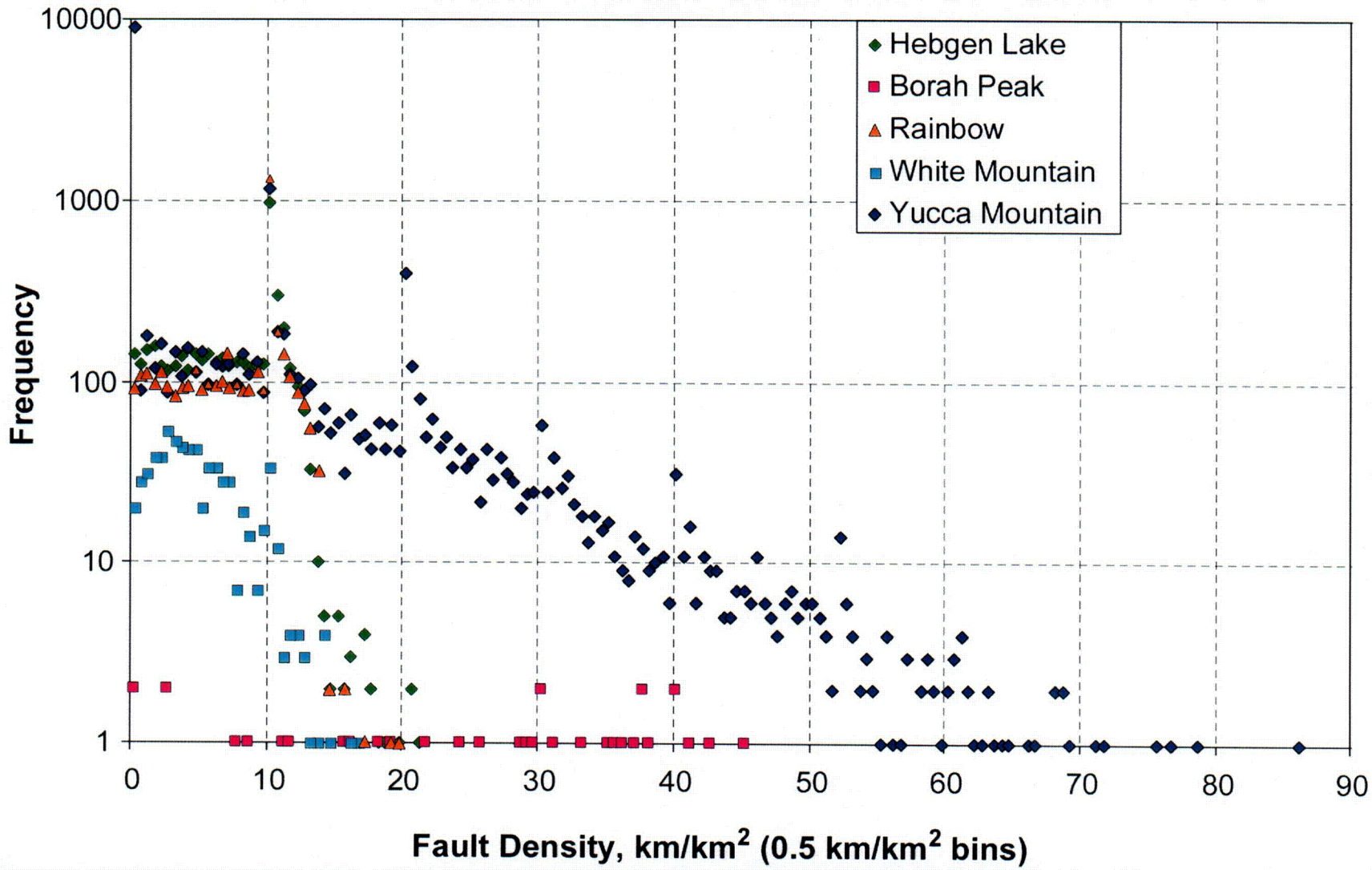


Solitario Canyon Fault



500 Realizations
Assume all WPs within fault zone fail
Maximum time for potential dose (event at 100 yr.)

Fault Density Analysis Results



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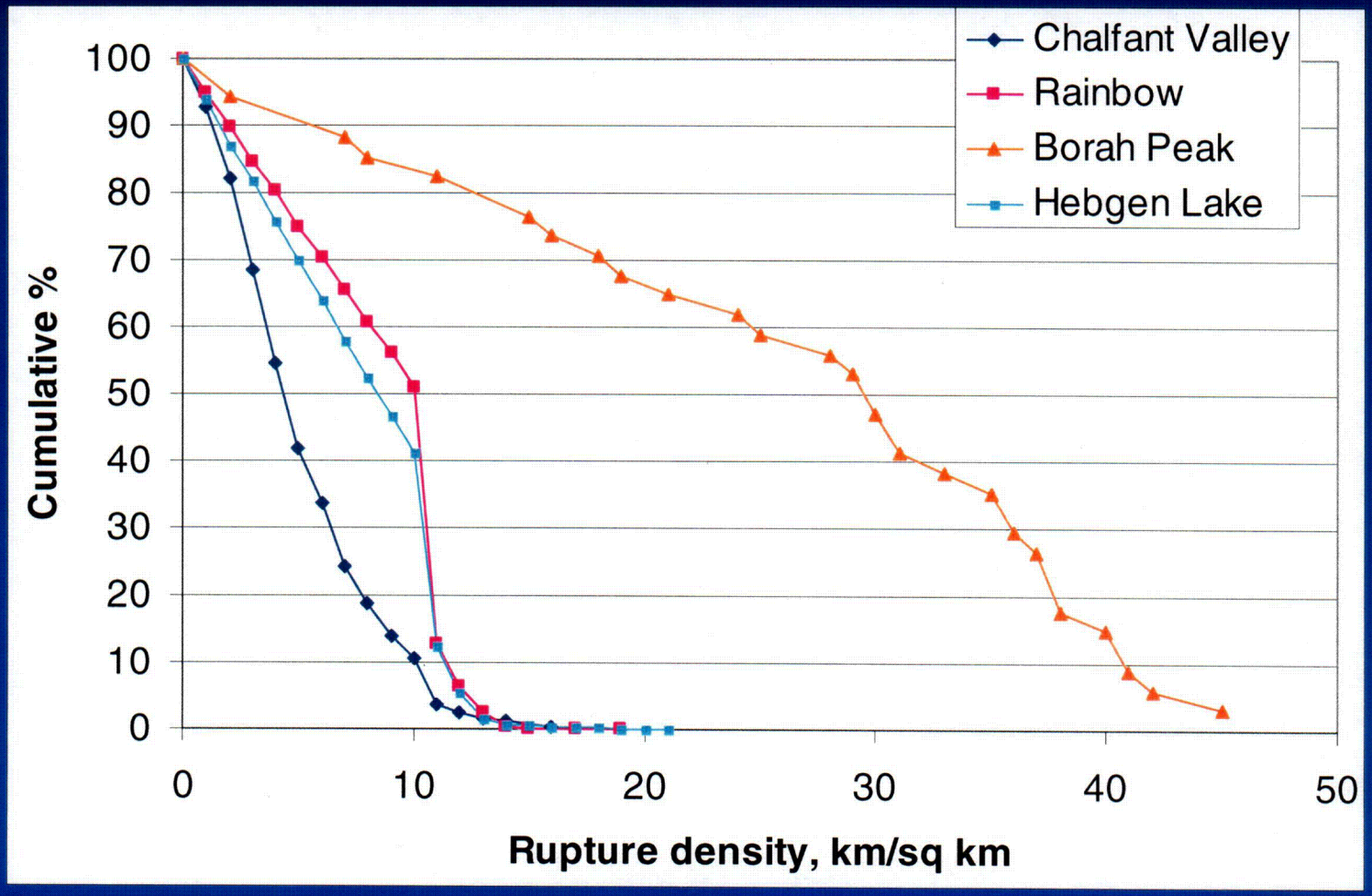
METHODOLOGY II - Rupture Trace Length Densities



– aka, rupture trace length per unit area

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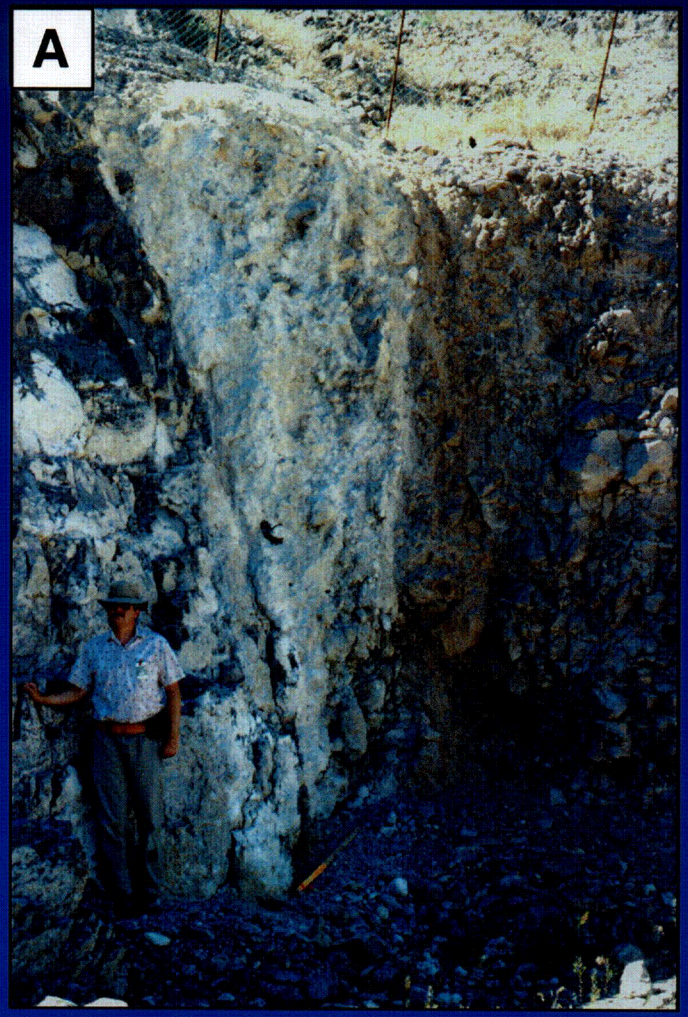
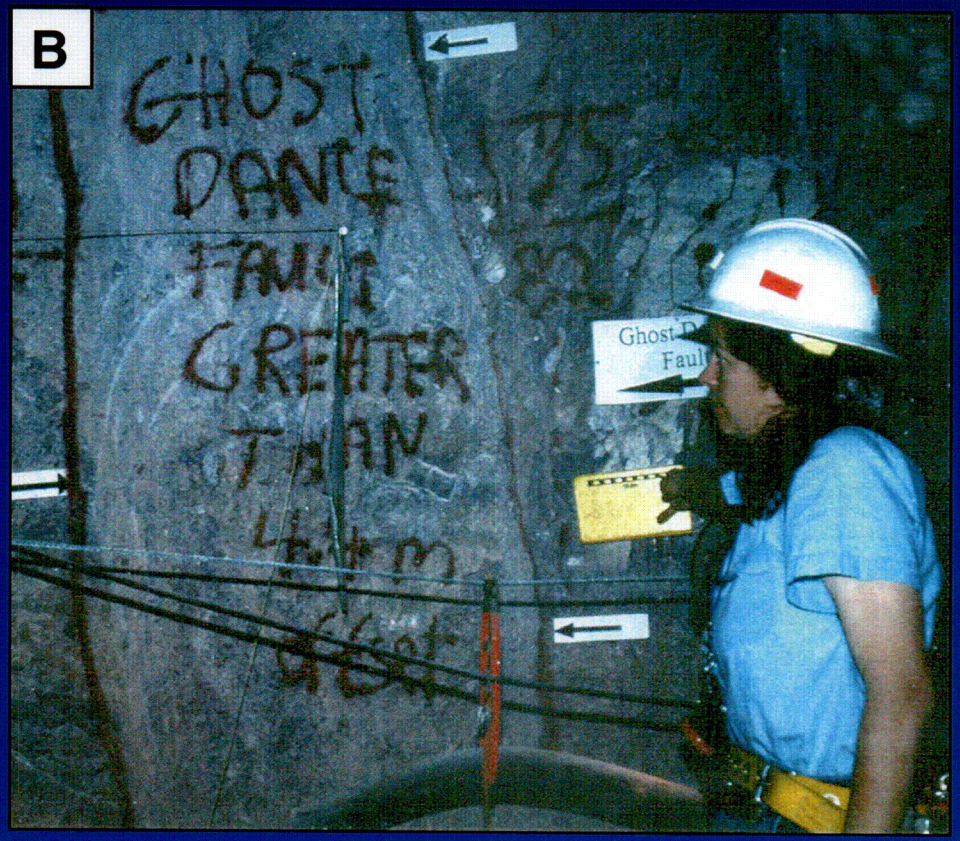
METHODOLOGY I - Fault Widths





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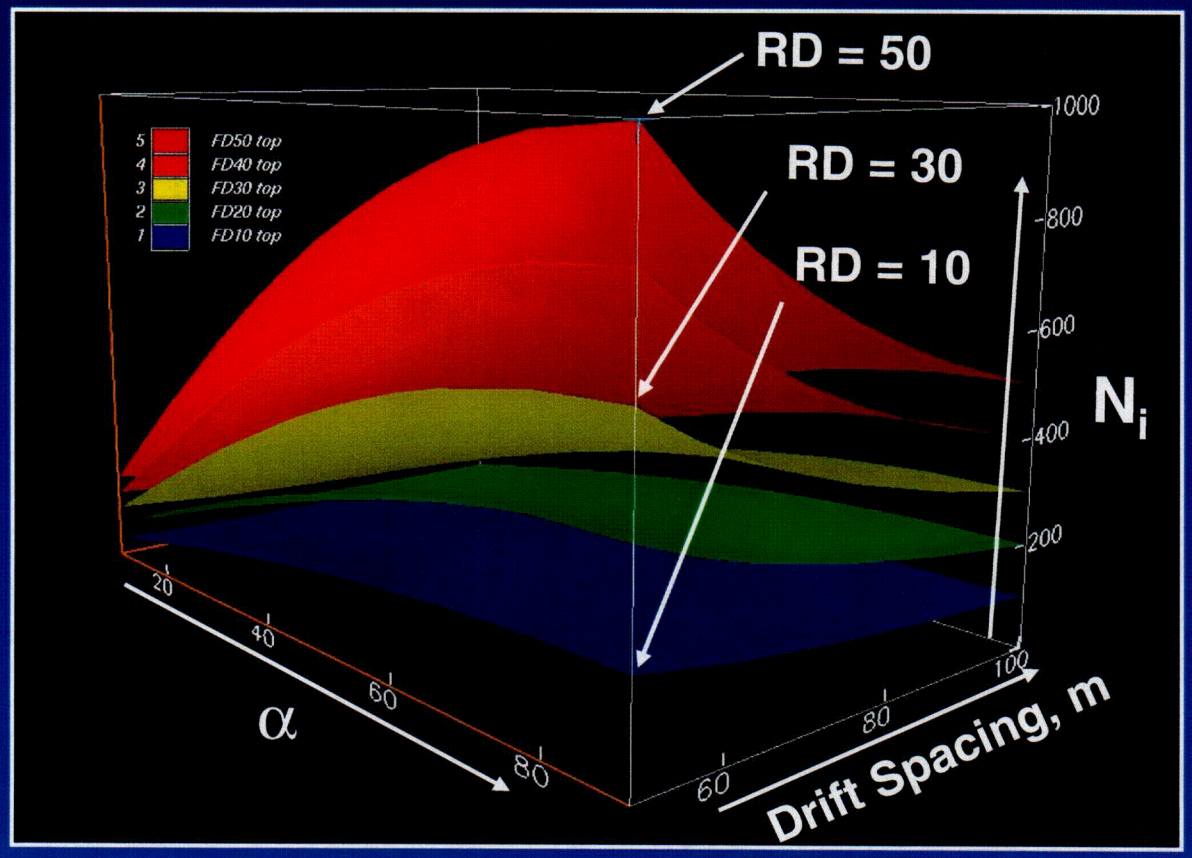
METHODOLOGY II - 3D Graphs



RD = km/km²

- number of rupture/drift intersection (N_i) depending on variables, such as:
  - rupture density, RD
  - rupture trend versus drift orientation, α
  - drift spacing

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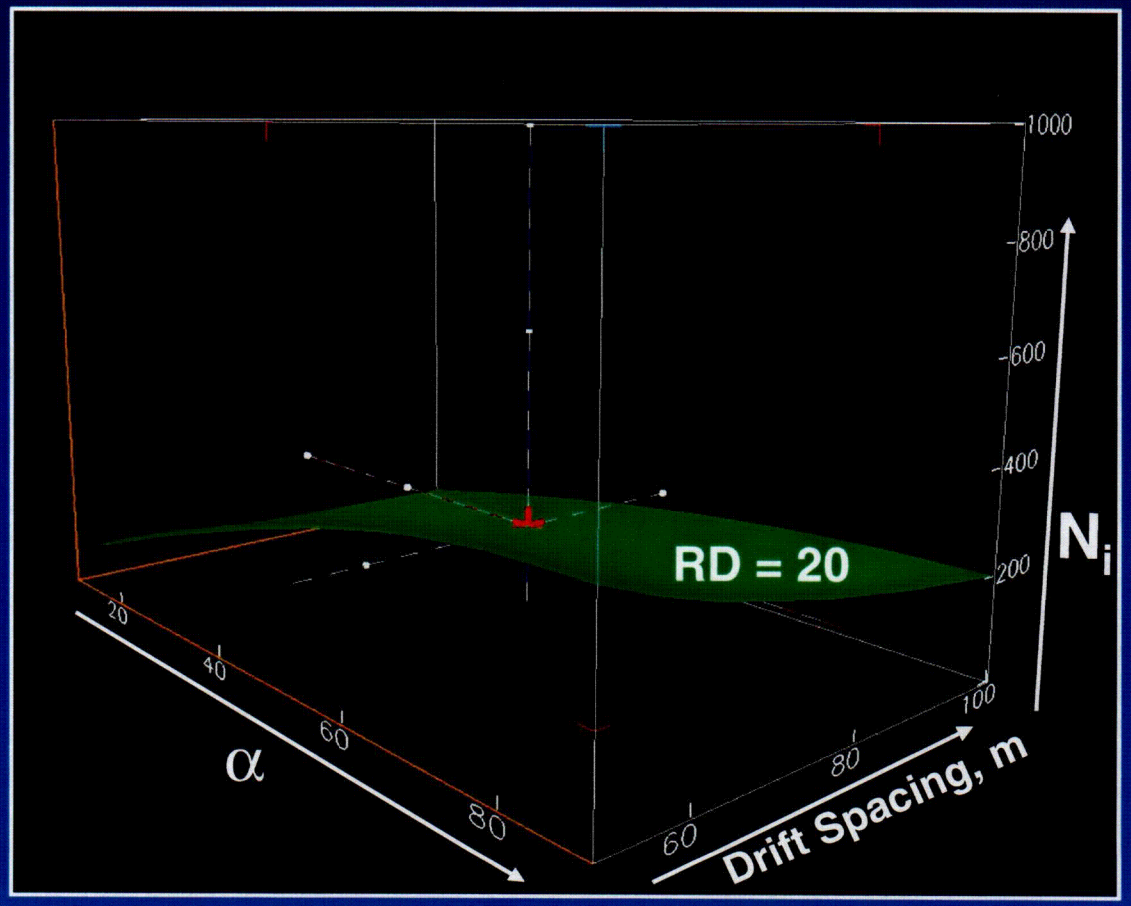
Example of Analysis using 3D Graph



- For example, using the following values:

  RD = 20 km/km^2
  α = 50°
  Drift spacing = 80 m
  N_i = 191 intersections

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